VOLUME 2

APIC TEXT

OF INFECTION CONTROL AND EPIDEMIOLOGY

4TH EDITION

APIC

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VOLUME II

Section 5

Prevention Measures for Healthcare-Associated Infections

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Urinary Tract Infection

Author(s): Harriette Carr, RN, MSN, CIC
Infection Preventionist

Carmichael, CA

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Abstract

It is known that the urinary tract is a very common source of infection. There are risk factors that can assist in the diagnosis, and there is a growing trend for antibiotic resistance in the causative organisms. Susceptibility to urinary tract infection is common to all people, and specific groups are more susceptible than others.

The use of indwelling urinary catheters at some time in a hospital stay is known as a risk factor for infection, and the rate of bacteriuria development after a single catheterization ranges between 1 and 20 percent. Rates of healthcare-associated urinary tract infections have decreased over time, but they still remain the most frequently identified healthcare-associated infection.

Key Concepts

- The urinary tract is normally sterile.
- Urinary tract infections cover a range of syndromes from asymptomatic cystitis to pyelonephritis and sepsis.
- Most instances of bacteriuria are asymptomatic and do not warrant treatment.
- Urinary tract infections are the most commonly occurring healthcare-associated infections.
- The indwelling urinary catheter is one of the most commonly used medical devices in the United States.
- Risk factors for development of a urinary tract infection follow this mnemonic:
  - Sex: female gender and sexual activity
  - Age: very young males and advanced age
  - Diabetic: especially type 2 females
  - Debilitated: all ages and all genders

- The Centers for Medicare & Medicaid Services identified hospital-associated catheter-associated urinary tract infections as one of first conditions for which hospitals will not receive additional reimbursement.

Background

PROPORTION OF POPULATION WITH URINARY TRACT INFECTIONS

Infections in the urinary system are the second most common type of infection falling well behind all of the various types of respiratory infections, but accounting for about eight million patient visits annually in the United States, or less than 1 percent of all outpatient visits. Twenty to 25 percent percent of females in the United States will develop a urinary tract infection (UTI) and about 20 percent of these individuals will develop recurrent infections. Even in children, UTIs are more common in female gender children under the age of 2.[1]

The urinary system consists of the urethra, bladder, ureters, and kidneys and is generally considered to be sterile. Thus, by definition, the term UTI means a bacterial or fungal infection of the urinary tract.[2]

UTI is a nonspecific term covering a wide range of disease conditions, ranging from asymptomatic bacteriuria, urethritis, or cystitis, to pyelonephritis to urinary sepsis. In some settings these infections are divided into *lower tract infections*, referred to as cystitis, and *upper tract infections*, referred to as pyelonephritis. Cystitis is an inflammation of the bladder after bacterial adhesion or invasion of the bladder wall. It may be either asymptomatic or symptomatic. Acute uncomplicated cystitis is the most common type of UTI in adult women.[2]Pyelonephritis is a serious infection with substantial morbidity, which can lead to bacteremia, sepsis, and renal abscess. Acute cystitis and acute pyelonephritis are generally considered uncomplicated infections when they occur in healthy, nonpregnant, nondiabetic adult women of childbearing age. UTI in any other female population, including postmenopausal women and pregnant women, men over the age of 35, and diabetics is considered complicated.[1,2]The genitourinary system is the source of severe sepsis in 9.1 percent of all cases annually with a resulting genitourinary-related mortality of 16.1 percent.[3]

Not to be confused with other forms of cystitis, *interstitial cystitis*(IC) is a disorder that causes chronic abdominal pain and urinary symptoms, particularly frequency and dysuria, but does not involve an infection. It is now frequently referred to as *painful bladder syndrome*(PBS).[4]The term IC/PBS includes all cases of urinary pain that cannot be attributed to other causes, such as infection or urinary stones. The term *interstitial cystitis*is used alone when describing cases that meet all of the IC criteria established by the National Institute of Diabetes and Digestive and Kidney Diseases. IC/PBS symptoms are different from individual to individual and fluctuate over time within the same individual. In women, they may acerbate during the menstrual cycle. As this is not an infectious process, this condition is not discussed in this text.[4,5]

Susceptibility to UTI is common to all people; however, there are specific groups that are more susceptible than others. These groups include male infants, all females and especially sexually active females, people with diabetes, elderly individuals, immunosuppressed individuals, patients with spinal cord injuries, patients with indwelling urinary catheters and stents, and patients with urological abnormalities.[2,4]Pregnant individuals are no more prone to UTIs than other sexually active women, but

their infections are more likely to travel to their kidneys.[1] Each of these risk groups is discussed individually.

Basic Principles

Made entirely within the confines of the internal structures of the body, urine is normally sterile. Urine has no humoral or cellular defenses against bacterial growth. Chemical balances within urine, such as pH, osmolality, glucose, and organic acids, modulate bacterial growth but do not prevent it. The unidirectional flow of urine helps to minimize UTIs by its flushing action, although a thin film of urine remains in the bladder after emptying. Any bacteria present in this film of urine are removed by mucosal cell production of organic salts. Anything that interferes with the body's ability to defend itself against uropathogenic bacteria increases the likelihood of development of infection. Examples of interference with defenses include: volume depletion in decreased fluid intake or dehydration, sexual intercourse, urinary tract obstruction, instrumentation, use of catheters not drained to gravity, pelvic examinations, and vesicoureteral reflex.[5]

Bacteriuria is the most recognizable change that occurs in urine with infection. Coliform bacteria or enterococci from the fecal flora or by *Staphylococcussaprophyticus*from skin flora usually cause cystitis. The diagnosis of cystitis in women is made by identifying pyuria and significant bacteriuria in the presence of cystitis symptoms.[5] These hallmarks are easily identified on urinalysis and contribute to the diagnosis of infection. Other causes of urinary inflammation exist and cause nonmicrobial inflammatory changes in the urinary system. Nonmicrobial disorders are symptomatic and frequently accompanied by pyuria, but have no identifiable microbiological agents associated with them. The diagnosis for these disorders is established by ruling out any bacterial cause for the symptomatology. IC is an example of this situation.

Definition Of Terms

BACTERIURIA

Bacteriuria is the presence of bacteria in the urine.

Asymptomatic Bacteriuria

Asymptomatic bacteriuria is the absence of symptoms in the patient with the presence of bacteria in an appropriately collected urine specimen. As the distal one third of the female urethra is contaminated with bacteria, it is common for urine specimens to have low colony-forming unit (cfu) counts. In the elderly female population, this situation may be referred to as *benign bacteriuria of the elderly* (see discussion under Elderly for further details).[2]

Catheter-associated Bacteriuria

The presence of an indwelling urinary catheter causes an inflammatory reaction in the urinary tract. Bacteria are allowed to ascend up both the internal and external surfaces of the catheter into the bladder thereby defeating the normal defenses of the bladder. Once established in the biofilm on the catheter surface, bacterial growth will follow an expected growth curve. Bacteriuria is often acquired as a function of the time the catheter remains in place. Migration to the bladder can occur within 1 to 3

days.[6] Bacteriuric patients may have both pyuria and bacteriuria on urinalysis. The majority of bacteriuric patients are both asymptomatic and afebrile. In more than 95 percent of the cases, this simply represents colonization of the urinary tract without obvious signs of infection.[2]

CYSTITIS

Cystitis is a generic nonspecific term for inflammation of the bladder. Symptoms include an urge to void (urgency), inability to start micturition (hesitancy), frequent voiding of small amounts of urine (frequency), burning on urination (dysuria), and suprapubic tenderness.[2] Bladder infections are often self-limiting, but antibiotic treatment will shorten the duration of symptoms. Single dose therapy has not proven to be as effective as short course therapy of 2 to 3 days of treatment.[1] According to the practice guidelines developed by the Infectious Diseases Society of America (IDSA) and the European Society for Microbiology and Infectious Diseases, the optimal treatment for acute uncomplicated cystitis is nitrofurantoin monohydrate/macrocrystals 100 mg twice daily for 5 days, or trimethoprim-sulfamethoxazole 160/800 mg twice daily for 3 days. The second regimen can be given if the local resistance rates of uropathogens causing acute uncomplicated cystitis do not exceed 20 percent or if the infecting strain is known to be susceptible.[7]

EPIDIDYMITIS

Acute epididymitis results from bacterial invasion overwhelming the normal defense mechanisms of the male urinary tract. Most cases result from retrograde ascension of organisms from the urethra, prostate, ejaculatory duct, or vas deferens. Risk factors vary with age. In men older than 35 years of age, the typical organisms that cause UTIs, especially *Escherichia coli* and pseudomonads, are the causative agents. In younger men who are sexually active, the most common pathogens are *Chlamydia trachomatis*and *Neisseria gonorrhoeae*.[8]

INCONTINENCE

Urinary incontinence affects millions of individuals, many of whom fail to report it to their care providers due to embarrassment or misconceptions regarding its management. Urinary incontinence generally results from either bladder or urethral dysfunction. Urge incontinence and overflow incontinence are related to bladder dysfunction, whereas stress incontinence is related to urethral dysfunction. Each of these types of incontinence is diagnosed and managed in a different manner. Not considered to be an infectious problem, urge incontinence can result from the urinary frequency associated with symptomatic UTIs. In this setting, especially in the elderly, there is difficulty getting to toileting facilities in time to prevent apparent incontinence.[9]

INDWELLING URINARY CATHETER

An indwelling urinary catheter is a drainage tube that is inserted into the urinary bladder through the urethra and left in place, connected to a drainage bag (including leg bags). It is also called a "Foley" catheter. This does not include suprapubic, external urinary devices (EUD) sometimes called condom catheters, straight intermittent catheters, or nephrostomy tubes. This definition does include indwelling urethral catheters that are used for intermittent or continuous irrigation.[10]

PYELONEPHRITIS

Pyelonephritis is often described as an *upper urinary tract infection*to differentiate it from cystitis. Pyelonephritis occurs as both an acute and a chronic infection. Acute pyelonephritis can be superimposed on chronic infection. Acute pyelonephritis usually ascends from the bladder into the renal parenchyma. Rarely acute pyelonephritis is the result of hematogenous seeding from infection in a distant site unless an underlying problem such as obstruction exists. Children with acute pyelonephritis should be examined for obstructive disease, as this is the likely cause of their disease. Elderly males may present with enlarged prostates or other parenchymal disorders. Imaging studies may be used in assessing acute pyelonephritis to identify alterations in renal parenchyma, perinephric fluid, nonrenal disease, gas-forming infections, hemorrhage, inflammatory masses, or obstruction. Patients with acute pyelonephritis may or may not have symptoms of concomitant cystitis.[3,10,11]

Symptoms of acute pyelonephritis usually develop over hours or over the course of a day and will differ in children, males, and the elderly. In males and children, this infection should be considered as complicated until proven otherwise.[3]In most patients with uncomplicated pyelonephritis, infection is caused by specific uropathogenic strains of *E. coli*that possess adhesions that permit ascending infection of the urinary tract.[11]

Identified risk factors for the development of pyelonephritis in women include sexual activities, new sexual partner, recent spermicide use, recent UTI, maternal history of UTIs, diabetes, smoking, and incontinence.[12]

Acute Pyelonephritis

Acute pyelonephritis is differentiated from acute cystitis by the presence of unilateral costovertebral angle (CVA) tenderness and abrupt onset of fever greater than 38.9ºC (103ºF). It usually manifests as unilateral CVA tenderness despite the pathological presence of bilateral infection. Acute pyelonephritis may resemble renal abscess in some patients. An episode of acute pyelonephritis may lead to significant renal damage, kidney failure, abscess formation, sepsis or sepsis syndrome, septic shock, or multiorgan system failure. In the frail elderly, the only notable presenting sign may be a change in mental status because of the prevalence of bacteriuria, frequency, urgency, incontinency, and indwelling catheter use in this patient population.[3,7]

Chronic Pyelonephritis

Chronic pyelonephritis results in shrunken distorted kidneys and collection systems. There is decreased blood supply to the kidneys, which further impairs the normal body defenses. This limits the penetration of antibiotics into the infected areas and diminishes the ability of white blood cells to defend against infection. Bacteriuria is present intermittently but will be present over long periods of time and will persist after short and inadequate treatment.[6]

PYURIA

Pyuria is the presence of increased numbers of polymorphonuclear leukocytes in the urine and is evidence of an inflammatory response in the urinary tract.[13]

Epidemiology

Actual rates of UTIs are hard to determine, as there is no national database for reporting this type of infection. Estimates can be made looking at national data. In 2009 to 2010, of 1.2 million ambulatory care visits that were coded for the primary diagnosis and visit setting, 59,754 (4.8 percent) were related to the genitourinary system; 2,488 (0.2 percent) were diagnosed as cystitis and other disorders of the bladder; and 9,759 (0.8 percent) were diagnosed as urinary tract infection, site not specified.[14]

PATHOGENS

Gram-negative bacilli and enterococci are the primary enteric bacteria that can grow in human urine. The presence of bacteria in urine is almost always preceded by intestinal colonization by the infecting bacteria. *E. coli* is the predominant aerobic Gram-negative organism of normal bowel flora, and thus is the most common organism isolated from UTIs. About 95 percent of all UTIs are a single isolated bacterium. In uncomplicated UTIs and pyelonephritis, 70 to 95 percent of the isolated organisms are *E. coli*and other Enterobacteriaceae. Recurrent UTIs and pyelonephritis may be caused by a wider variety of organisms with a lower rate of *E. coli* isolation, some of which have increased antibiotic resistance. Other Gram-negative organisms such as *Pseudomonas, Serratia, Stenotrophomonas*, and *Acinetobacter*may be implicated if the infection is healthcare related.[5]Table 33-1 outlines the microbial species most often associated with uncomplicated and complicated UTIs.

Table 33-1 Bacterial Etiology of Urinary Tract Infections

Bacteria	% Uncomplicated	% Complicated
Gram negative		
Escherichia coli	70–95	21–54
Proteus mirabilis	1–2	1–10
Klebsiella species	1–2	2–17
Citrobacter species	< 1	5
Enterobacter species	< 1	2–10
Pseudomonas aeruginosa	< 1	2–19
Other	< 1	6–20
Gram positive		
Coagulase-negative staphylococci	5–10*	1–4
Enterococci	1–2	1–23
Group B streptococci	< 1	1–4
Staphylococcus aureus	< 1	1–23
Other	< 1	2

* *Staphylococcus saprophyticus.*
Adapted from Hooton TM. The current management strategies for community-acquired urinary tract infection.*Infect Dis Clin North Am* 2003 Jun;17(2):303–332.

E. coli possesses several virulence factors that make it a very important bacterial cause of UTIs. Strains that have O-, K-, and H-antigen serogroups, adherence pili, and hemolysin production have increased virulence. Comparing two geographically separate communitywide outbreaks of *E. coli*UTIs, researchers identified unique O-antigen and *E. coli*characteristics in the study populations. Researchers were able to identify clusters of infection, but were not able to identify transmission routes. This raises the question of the role of communities in the spread of unique bacteria and subsequent identified infections.

Rates of antibiotic-resistant bacteria are increasing and can be reflected in the percentages of isolates for different types of UTIs. Because of the continuing use of antibiotics, fungi and yeast are more frequently being identified as the causative agents. In turn, there has been development of resistance to the antifungal agents commonly used.

DIAGNOSIS

Specimen Collection

Analysis of a voided specimen that is collected in a manner with as little contamination as possible is the most desirable sample. Many techniques have been attempted to obtain clean specimens, especially from females. So-called clean catch midstream techniques can produce a reputable specimen when obtained correctly and with care. In a "clean catch" sample the genital area is washed with a mild soap beginning at the top of the labia washing downward toward the genitals to prevent bacteria from the genital area contaminating the specimen and causing confusion with the test results. As it is not uncommon for urine in healthy individuals to have low counts of bacteria, when possible, urine specimens should be collected as a "midstream" sample. All samples regardless of method of collection should be placed in a sterile collection container.[1]

Obtaining a specimen directly from the bladder by an invasive technique occasionally may be necessary if contamination cannot be avoided, the patient is unable to cooperate, or in some research settings. Insertion of an indwelling urinary catheter to obtain urine specimens is unwarranted. Intermittent straight catheterization kits are available for this purpose. In infants and young children, special collection devices (wee-bags) or bladder catheterization and/or aspiration can be used to collect an appropriate urine specimen. Leg bags and wee-bags in adults are inappropriate methods of collecting urine specimens.

In patients with indwelling urinary catheters, urine for culture should be collected from the sampling port using aseptic technique. Specimens should not be obtained from the urinary drainage bag nor should the specimen be obtained by disconnecting the catheter from the drainage tubing. Urinary catheter tips should not be cultured and are not acceptable for the diagnosis of a UTI.

Urinalysis

In a symptomatic individual, the presence of white blood cells and bacteria is suggestive of a UTI. Tests for leukocyte esterase and nitrites serve as surrogate markers for pyuria and bacteriuria and are available in a quick test format. Urine dipstick tests are useful in all patient populations to rule out the presence of infection if both leukocyte esterase and nitrites are negative. Positive dipstick results need to be confirmed by more sensitive methods, including culture and sensitivity patterns of identified organisms.[15]Not all organisms reduce nitrate to nitrite; therefore, false-negative results will occur. Pyuria alone with asymptomatic bacteriuria is not an acceptable reason for antibiotic treatment.

Culture

Microbiological diagnosis of a urine specimen collected aseptically from the catheter usually requires a culture result of ≥ 10^5cfu/mL of an organism. Lower quantitative counts may be diagnostic in some patients or may predict subsequent development of higher quantitative counts. The recovery of three or more species generally indicates that the specimen has been contaminated through faulty collection or delay in transport to the laboratory.

CHILDREN

The urinary system is second only to the respiratory system as the site of bacterial infections in children. The presence of bacteriuria in childhood is related to gender and age. In the neonatal period, infection is three to five times greater for males than females. For male infants, neonatal circumcision substantially decreases the risk of UTIs. Shaikh et al. reported that in febrile male infants younger than 3 months of age, UTI was present in 2.4 percent (confidence interval [CI], 1.4 to 3.5) of circumcised males and 20.1 percent (CI, 16.8 to 23.4) of uncircumcised males.[16] Collection of an appropriate reliable specimen must be done to confirm the diagnosis in the neonatal age group.

Approximately 2.2 percent of girls under the age of 2 develop a UTI. Risk factors for young girls include:

- History of maternal UTI
- Family history of vesicoureteral reflux
- History of dysfunctional voiding patterns
- Constipation

Although often reported as a cause, direction of wiping with toilet paper is not a risk factor. Identified risk factors include bubble baths and prolonged soaking in the bathtub, excessive holding of urine, and delayed bladder emptying.[17] Prolonged retention of urine may permit incubation of bacteria in the bladder. Voiding dysfunction is not usually encountered in a child without neurogenic or anatomic anomalies until the child is in the process of achieving daytime urinary bladder control. A child with an overactive bladder due to uninhibited detrusor contractions may attempt to prevent incontinence during a detrusor contraction by increasing outlet resistance. This can be achieved by using posturing maneuvers, such as tightening of the pelvic floor muscles, applying direct pressure to the urethra with the hands, or squatting on the floor and pressing the heel of one foot against the urethra (the Vincent curtsy). As a result of these maneuvers, bacteria-laden urine in the distal urethra may be forced back into the bladder essentially causing urethrovesical reflux. This situation needs to be managed with both behavior changes and medications.[18]

Diagnosis is difficult in little girls, and bladder urine should be collected via intermittent catheter or direct aspiration from the bladder until the child is potty trained.[17] Children usually have nonspecific symptoms, especially those under the age of 2 years. Symptoms may include:

- Fussiness
- Fever
- Anorexia
- Emesis
- Abdominal pain
- Neonatal jaundice

- Poor weight gain
- Enuresis
- Hematuria

A voiding cystogram is essential in the management of UTIs in all girls under the age of 5 and all age boys.[17]

ADULT FEMALES

About one out of every four women will have a history of having had a UTI. UTIs are 14 times more frequent in women than men. Many women will experience a recurrent UTI that can be classified as a relapse or reinfection, depending upon when it occurs in relationship to their first infection.[1]Factors contributing to the increased incidence of UTIs in women are: (1) shorter urethra; (2) contamination of the lower third of the female urethra with organisms from the vagina and rectum; (3) tendency not to empty their bladders as completely as men do; and (4) bacteria that enter the bladder during intercourse. Close proximity to the anal and vaginal areas provides easy access for potential infecting bacteria.

*Staphylococcus saprophyticus*is an unusual pathogen and is not generally associated with UTIs in the general population. However, this organism is present in 7 to 26 percent of infections in young, sexually active females. In outpatient settings, this is the number two causative organism in these populations. Investigations have implicated exposure to diaphragms treated with spermicides as the most likely risk factor. Spermicides have nonspecific toxic effect on normal vaginal flora. The secondary risk factors have been identified as history of a previous UTI with any other bacterial agent, delayed postcoital micturition, multiple sex partners, and more frequent sexual intercourse.[1]

Recurrent UTIs are symptomatic UTIs that follow successful resolution of an earlier infection, usually after appropriate treatment. Most recurrent infections represent reinfection with the same organism as the first infection and they occur most commonly in otherwise healthy young women with anatomically and physiologically normal urinary tracts. They have the same risk factors as previously presented.[19]

Pregnancy

Approximately 4 to 10 percent of pregnant women develop asymptomatic bacteriuria, with 1 to 4 percent experiencing their first incidence of acute cystitis. Women with a history of UTIs are more likely to develop UTIs than those without this history coupled with increased maternal age. Some differences are present in ethnic groups, but causes for this are poorly understood.[20]

Risk factors for pregnant women include multiparity, past history of UTIs, sexual activity,[21]increased blood supply with increased renal filtration, changes in hormonal levels, and shifts in the position of the urinary tract as the pregnancy develops. The ureters have tonic relaxation secondary to massive hormone production. Urinary tract relaxation coupled with increased urinary volume allows urine stasis to develop. These changes allow the bacteria to travel more freely up the ureters into the kidneys and may explain the increased frequency of upper tract infections. The rate of upper tract infection has been reported to be as high as 33 percent in some studies. Women should be screened for bacteriuria on their first prenatal visit.[13,20]Untreated upper UTIs have been associated with poorer outcomes during pregnancy. Untreated asymptomatic bacteriuria is a risk factor for acute cystitis (40 percent) and pyelonephritis (25 to 30 percent) in pregnancy. Pyelonephritis occurs in approximately 2 percent of all

pregnancies. *E. coli*is the most common causative agent, accounting for between 80 and 90 percent of all cases. These infections result from periurethral colonization with fecal flora that contributes to ascending infections. Other pathogens and their frequencies identified in these infections are as follows: [21]

Table 33-2 Pathogens and their frequencies

Klebsiella pneumoniae	5 percent
Proteus mirabilis	5 percent
Enterobacter species	3 percent
Staphylococcus saprophyticus	2 percent
Group B beta-hemolytic streptococcus (GBS)	1 percent
*Proteus*species	2 percent

For this reason, prompt treatment of asymptomatic bacteriuria is more appropriate in pregnant women than in other patient groups.[13]Important considerations related to group B streptococcus bacteriuria are relevant to the obstetrical workup.[22]In 2004, the U.S. Preventive Services Task Force issued a grade A recommendation for the "screening for asymptomatic bacteriuria with urine culture for pregnant women at 12 to 16 weeks gestation." This recommendation was reaffirmed on review in 2008 on the basis of good evidence that, in this patient population, treatment of asymptomatic bacteriuria reduces the incidence of symptomatic UTIs, low-birth-weight babies, and preterm deliviery.[23]

Initial diagnosis in this patient population can be difficult. The usual complaints of increased frequency, nocturia, and suprapubic pressure are not particularly helpful because most pregnant women experience these as a result of increased pressure from the fetus. Most pregnant women with pyelonephritis present with the following signs and symptoms:

- Fever (often the temperature is very high)
- Chills
- Nausea and vomiting
- CVA tenderness or flank tenderness

Because of the frequency with which contractions occur during treatment, pregnant patients with pyelonephritis should always be admitted for acute care.[3]Patients with pyelonephritis require hospitalization, fluid replacement, and initial intravenous antibiotics until they remain afebrile for 24 hours. Antibiotics that are used to treat these infections have not been found to be associated with increased risks of birth defects when used during pregnancy. However, trimethoprim is a folic acid antagonist and its use during the first trimester has been associated with structural defects such as neural tube and cardiovascular defects. Additionally, sulfamethoxazole can persist in neonatal circulation when administered near the time of delivery. If possible, trimethoprim-sulfamethoxazole should be avoided after 32 weeks of gestation.[22]

ELDERLY

UTIs for females occur across all age groups, but do increase in frequency as females age. Other factors include postmenopausal women due to estrogen deficiency that contributes to a decrease in lactobacilli colonization in the vaginal area, past history of UTIs, diabetes, sickle cell disease or sickle cell trait, or kidney stones.[1] As the population ages and more elderly individuals are institutionalized, the rates of UTIs increase. Close proximity of living arrangements, dementia, confusion, device use, and debility all play a role in increased rates of infection in this population. *E. coli*accounts for approximately 30 percent of hospitalizations for community-onset bacteremia. Community rates of *E. coli* bacteremia are affected by rates of incontinence and both current and recent use of indwelling urinary catheters.

Benign bacteriuria occurs in elderly females who often have few or no symptoms. Relaxation of the pelvic musculature allows for varying degrees of cystocele or rectocele. Benign bacteriuria is often identified on routine urinalysis collected for other purposes. It has been shown that these patients do not go on to develop symptomatic UTIs, ascending infection, or bacteremia. This situation does not warrant treatment.[2]

Clinical presentations of acute UTIs in healthy immunocompetent premenopausal women versus postmenopausal women will present with different symptoms. Premenopausal women present with more localized symptoms of infection such as frequent, painful, and burning urination. Postmenopausal women complain of more severe symptoms related to storage of urine, generalized lower abdominal pain, lower back pain, constipation, diarrhea, nausea, nocturnal incontinence, and urgency. Effects of menopause and sexual activity will play a role as risk factor for disease transmission in both healthy pre- and postmenopausal women.[24]

More study is needed in the treatment of females over the age of 65 to determine the role of age as a factor necessitating longer treatment regimens. Grover and colleagues suggest that uncomplicated UTIs in this group were frequently caused by *E. coli* and could be managed by sulfamethoxazole-trimethoprim in a manner similar to younger females. Complicated UTIs in the older female population may be caused by pathogens other than *E.coli*; however, suspicion should be based on the signs and symptoms of the patient, not on age.[25]

MALES

UTIs in males have a bimodal presentation with male infants and elderly males at risk. Between the ages of 3 months and 50 years, males seldom experience UTIs. Male infants have a higher rate of symptomatic UTIs that has been directly related to their circumcision status. Neonatal circumcision appears to reduce the UTI rate in boys by 90 percent. Asymptomatic bacteriuria is also unusual in male individuals.

A confirmed UTI in a young male mandates a thorough investigation of the urological system for structural abnormalities. Often the presence of a UTI is the key diagnostic presentation for abnormalities of this system. Diagnostic workups in a young male include a voiding cystourethrogram and a renal ultrasound. In young men with no history of structural abnormalities, sexual intercourse, particularly individuals who practice insertive anal intercourse, may be a risk factor.[26]

As males age, benign prostatic hypertrophy develops and residuals of urine remain in their bladders after voiding. This residual urine forms a nutritive media for bacterial growth. Standards for the diagnosis of UTI change with elderly males so that growth of only 1,000 cfu/mL may be indicative of a UTI. As with females, *E. coli*is the most commonly isolated pathogen. In the long-term care (LTC)

setting, *Proteus mirabilis*is a commonly isolated pathogen. As males age, their rates of UTI approach that seen in females. By age 80, 50 percent of males will have had a UTI.

Morbidity from infection is considerably higher for males; thus, their infections are often symptomatic and may lead to infections of the prostate, epididymitis, or testes. Chronic prostatitis is very difficult to eradicate and is a common cause of chronic bacteriuria in men.

UTIs in the male population are classified as complicated, and require a longer period of antibiotic treatment. Current recommendations are 7 days of a fluoroquinolones as empiric therapy. If epididymitis is suspected, treatment will be extended to cover 10 to 14 days and if prostatitis is suspected, 4 to 6 weeks.[23]

DIABETICS

Asymptomatic bacteriuria is more common in diabetic than nondiabetic women, with a prevalence of 26 percent. It is usually correlated with duration of diabetes and presence of long-term complications of diabetes, rather than with metabolic parameters of diabetic control.[27]Type 2 diabetic women with asymptomatic bacteriuria are more likely to develop symptomatic UTI than either type 1 diabetic women or nondiabetic women.[28]For type 1 diabetic women, sexual intercourse and oral contraceptive use in the week prior to the onset of symptoms significantly increased the risk of developing a UTI.[29]Diabetics are at risk for certain complications. About 75 percent of perinephric abscesses and all cases of emphysematous pyelonephritis have diabetes as comorbidity.[27]Treatment and follow-up of asymptomatic diabetic females have not demonstrated any benefits.[14,27]Diabetic women with asymptomatic bacteriuria suffered no renal function decline or hypertension in a long-term study of asymptomatic bacteriuria patients.[28]

Although *E. coli*is the most common infecting organism in nearly all patient groups, *Klebsiella*and group B streptococcus infections are more common in diabetic individuals.[19]There are no randomized trials to answer the question on appropriate duration of therapy for treatment of symptomatic UTI in diabetic patients. It has been recommended that these patients be considered as having a complicated UTI and therefore be treated for a period of 7 to 14 days.[27]

Catheter-Associated Urinary Tract Infections

Throughout history, references to devices inserted into the bladder to drain it can be found. Earliest accounts describe draining the male bladder to manage acute urinary retention. Urologists were expected to make their own catheters to address the unique needs of their patients. The early goal was to make a catheter flexible enough to fit under the hatband of the urologist so that the catheter could be taken from patient to patient. Early catheters were primarily used as surgical instruments to control bleeding after prostatectomy surgery. In 1927, Dr. Frederick EB Foley (1891 to 1966) designed the catheter that is currently called the Foley catheter. The current types of indwelling urinary catheters in use are very similar to Dr. Foley's original model. Changes from the first models include the addition of preconnected systems to reduce infection risks, an inflation cap, coatings to reduce catheter friction (hydrophobic), and coatings to diminish biofilm formation and reduce infection. Many coatings have been attempted without success, and currently the most successful coatings available on the market are

made of ionic silver and other noble metals. Catheters with antimicrobial coatings are available on the market.[30,31]

INCIDENCE OF CATHETER-ASSOCIATED URINARY TRACT INFECTIONS

UTIs are the most common infection encountered in healthcare and approximately 80 percent are associated with the use of indwelling urinary drainage devices. Twelve to 16 percent of patients who are admitted to acute care hospitals will have an indwelling catheter placed at some time during their hospital stay.[32]Approximately 5 percent of LTC residents will have their voiding habits managed by chronic indwelling catheters. Infections resulting from these devices are modest for most patients with low morbidity and mortality.[33]The daily risk of urinary tract infection from an indwelling urethral catheter ranges from 3 to 7 percent.[32]Gender differences exist in how infection occurs in catheterized patients. Males generally become infected from the intraluminal route from a contaminated drainage bag. Female contamination occurs from the transurethral migration of bacteria up the extraluminal surface of the catheter.[31]

Pyuria development in short-term catheterized patients is not indicative of infection and should not be used as a criterion for urine culture or as an indication for antimicrobial treatment.[34]Ninety percent of patients with significant bacteriuria are asymptomatic for any signs and/or symptoms of a UTI.[35]

Rates of healthcare-associated UTIs have decreased over time, but they still remain the most frequently identified healthcare-associated infection (HAI). Actual rates of HAIs are difficult to determine, especially for UTIs. Klevens and colleagues estimated the impact of HAIs in 2002, estimating that 36 percent of the reported infections were UTIs.[36]Newer data from Umscheid and colleagues examine the cost of preventable HAIs and establish an outcome measure for each type of infection.[37]Using Klevens' data, a case fatality rate of 2.3 percent, or the lowest incidence of death per infection, was calculated for UTIs.[37]

Strategies relevant to delaying the onset of bacteriuria in short-term catheterized patients will not necessarily work in chronic long-term patients.[32]Every patient's urethral catheter will become coated with biofilm and will become infected given enough time. The only way to prevent infection is to not use a catheter or to remove the catheter before bacteriuria is established.[34]Evidence-based practices by themselves do not prevent 100 percent of the infections in any setting.[37]More research needs to be done to better understand the role of bacterial strains that colonized devices such as urethral catheters and antibiotic sensitivity patterns for these organisms.

APPROPRIATE USE OF URINARY CATHETERS IN HEALTHCARE SETTINGS

The development of a CAUTI is associated with significant morbidity and some risk of mortality. It is estimated that CAUTIs extend a patient's length of stay between 0.5 day and 1 day and cost between $1,200 and $4700 (2009 dollars).[37]The patient's extended length of stay, development of antibiotic-resistant organisms, and increased costs have resulted in an emphasis on appropriate use of this device. Physician or nurse documentation of reasons for use of this device is often lacking, resulting in large numbers of inappropriate catheters being placed and their use being continued.[38]In the October 2008 Society for Healthcare Epidemiology of America (SHEA) and IDSA *Supplement on Strategies to*

Reduce Catheter Associated Urinary Tract Infections in Acute Care Hospitals, the authors note that although morbidity attributable to any single episode of catheterization may be limited, the high frequency of catheterization creates a substantial cumulative burden associated with it.[32]

Appropriate reasons for the use of an indwelling urinary catheter include:[35,39]

- Acute anatomic or functional urinary retention or bladder outlet obstruction
- Need for accurate measurements of urinary output in critically ill patients
- Perioperative use for selected surgical procedures
- To assist in healing open sacral or perineal wounds in incontinent patients
- Improve comfort for end-of life care if needed or patient preference

Inappropriate reasons for use of an indwelling catheter include:

- Convenience of nursing care
- Obtaining urine for culture or other diagnostic studies when the patient is able to cooperate and voluntarily void
- For prolonged postoperative duration without appropriate indications[35,39]

Further refinements to the list of appropriate and inappropriate uses have been made by many healthcare systems. The goal in this movement is to ensure that the device is used appropriately for as short a period of time as is appropriate for each individual patient. Although there have been several articles related to decreasing catheter usage, it is important to note that not all of these studies measured CAUTI as an outcome or identified a decrease in CAUTI rates.

SPECIAL PATIENT POPULATIONS

Intensive Care Unit

With the identification that the closed drainage system could reduce the incidence of CAUTI approximately 30 years ago, many efforts have been made to decrease the rates of CAUTI in critical care patients. Yet, in many hospitals, the initial catheter drainage system inserted by the emergency department has to be manipulated and modified by intensive care unit (ICU) staff to facilitate monitoring of patients' urinary output. The impact that this has on the infection rate for ICU patients warrants investigation. Many small studies have attempted to look at the rates and outcomes of infections in the ICU patient population. These studies have been underpowered to demonstrate whether these infections independently increased patient morbidity and mortality. In an extensive study to identify the development of ICU-associated UTIs, Laupland and colleagues from the Calgary Health Region reviewed 4,465 patients admitted 4,915 times to an ICU for 48 hours or longer. Using a standard definition, the overall incidence rate of ICU-associated UTI was 9.6 per 1,000 ICU days, with a variation from year to year that may have resulted from other infection prevention initiatives. Female patients and medical ICU patients were at highest risk of development of infection. Although these infections could serve as a marker for increased morbidity in this patient population, they did not increase their mortality risk.[40]

Overuse of an indwelling urinary catheter in the ICU patient population is an identified problem. Early justification of use during critical monitoring is evident, but continued use is often unjustified. Risks associated with the overuse of catheters in ICU include CAUTI, increased discomfort, and restricted

mobility—all things that contribute to delayed recovery or extended stay in the ICU.[41] Huang and colleagues developed an action plan to reduce the prolonged use of indwelling catheters in the ICU by requiring nursing staff to remind physicians on a daily basis to remove catheters that were no longer needed 5 days after insertion. This demonstrated a statistically significant decrease in the duration of urinary catheterization, rates of CAUTI, and additional costs of antibiotics to manage CAUTIs.[42] As more and more sophisticated technology is utilized in the intensive care area to monitor the vital signs of patients, other methods of obtaining necessary data besides an indwelling urinary catheter need to be considered. The presence of an indwelling urinary catheter and the dwell time of the device are the two fundamental risk factors for the subsequent development of a CAUTI. Systems have been developed to remind physicians to order the removal of indwelling drainage devices. Most of these systems rely on nurses to remind the physician to order the removal. Success has been demonstrated for short periods of time. For appropriate patients who must have an indwelling urinary catheter, use of a device with improved coating technology should be considered as an adjunct method to assist in the management of the risk factors.

Regardless, the rate of catheter use in the ICU is declining and the CAUTI rates have significantly declined in all major adult ICU types in facilities reporting to the Centers for Disease Control and Prevention (CDC). This suggests that infection control measures in some ICUs are succeeding. As the rates fall it will become more important to develop new methods to monitor trends and measure improvement.[43]

Long-term Care

Approximately 1.5 million individuals live in LTC settings in the United States. Urinary incontinence affects upward of 60 percent of these residents. Long-term use of indwelling urinary catheters has been one way to manage their urinary incontinence. The use of indwelling urinary catheters in this patient population has increased the risk of CAUTI, bacteremia, and death. The Centers for Medicare & Medicaid Services has required valid medical reasons for the continued use of indwelling catheters. This emphasis has led to the decreased use of these devices. In a study of LTC residents in five states, Rogers and colleagues found that 12.6 percent of patients admitted to LTC have an indwelling catheter at the time of admission. The use of this device declines to 4.5 percent after 1 year.[44] Several predictors for use of a urinary catheter were identified, including paraplegia, quadriplegia, multiple sclerosis, male gender, diabetes, obesity, renal failure, skin conditions, deep vein thrombosis, aphasia, and end-stage disease. As diabetes is an identified independent risk for the development of UTI, and the presence of diabetes is not an indicator for use of a urinary catheter, this is a group of patients for whom other strategies to manage their urinary output needs to be implemented. Other methods for managing the voiding needs of male patients with obesity, multiple sclerosis, deep vein thrombosis, and communication problems warrant investigation.[44]

Rates of catheter use vary by geographic area and medical service. For example, in the aforementioned study, California, Florida, and Texas had greater use than New York.[44] In another study reviewing the use of indwelling urinary catheters in older surgical patients, 23 percent of all surgical patients admitted to LTC had an indwelling urinary catheter in place on admission. In this study, a surgical patient admitted with an indwelling urinary catheter had a greater risk for readmission to acute care for UTI than a surgical patient admitted to LTC without an indwelling urinary catheter. An additional finding of interest is that surgical patients with an indwelling urinary catheter had greater odds of death within 30 days than those admitted without an indwelling urinary catheter.[45]

Definition of infection in the frail elderly population in LTC has often been difficult to determine. This confusion has led to overuse of antibiotics and other treatments. The McGeer Criteria were developed in 1991 to provide standardized guidance for infection surveillance activities and research in nursing homes and other LTC institutions. The SHEA LTC Special Interest Group revised the criteria in 2012 to reflect (1) the changing patient population cared for in nonhospital settings; (2) the increase in the body of evidence-based literature about infections in the elderly in LTC settings; (3) the availability of diagnostics for infection surveillance; and (4) the updated acute care hospital definitions from the CDC's National Healthcare Safety Network (NHSN).[46]

For UTI without a catheter, the new definitions differ substantially from the original guidelines. The LTC definitions take into account the low probability of UTI in residents without catheters if symptoms are not present as well as the need for a urine culture for microbiologic confirmation. For more information, the reader is referred to the surveillance definitions.[46]

Surgical Patients

Short-term use of indwelling urinary catheters in certain surgical patients is widely accepted (Table 33-2). Perioperative catheter use is intended to relieve bladder dysfunction secondary to anesthesia, analgesia, and immobility. Use of the catheter has extended into the postoperative period secondary to patient-controlled anesthesia and transient neurogenic bladders. Most authorities suggest limiting use of catheters in this patient population to 48 hours or less. Wald and colleagues identified that rates of UTI were similar across all surgical services.[45]Further, they discovered that use of a catheter for more than 2 days increased the rate of infection twofold, compared with patients whose use was less than 2 days. Postoperative catheterization for more than 2 days was associated with increased mortality and decreased discharge to the patient's own home.[47,48]

Spinal Cord Injuries

Patients with spinal cord injuries present unique challenges for the management of their urinary systems. The level and completeness of injury affects the future functioning of the patient's bladder. Complete quadriplegia renders the patient typically totally unaware of the bladder. The patient may recognize some secondary clues of bladder function, such as sweating or chills. Female patients with spinal cord injuries are maintained on urinary catheters more often than males. Males are often maintained on condom catheters and, when possible, intermittent catheterization. Risk factors linked to the development of UTIs in individuals with spinal cord injuries are prior history of UTI, higher degree of functional impairment, and lack of exercise.[49]The rate of UTI is 2.5 episodes per year.

Table 33-2. Surgical Patients with Indwelling Urinary Catheters[47]

Table 33-3 Surgical Patients with Indwelling Urinary Catheters

	Orthopedic (*n*= 11,770)	Cardiac (*n*= 8,790)	Vascular (*n*= 3,657)	GI (*n*= 8,730)	All (*n*= 30,947)	*p* value
Age mean, years	76	72	73	75	74	< .001
Female sex, %	70.1	36.9	39.3	58.0	54.4	< .001

White race, %	90.9	89.5	85.8	87.0	89.0	< .001
Diagnosis justifying urinary catheterizations, %						
Urinary retention, %	1.7	1.5	1.8	2.5	1.8	< .001
Bladder outlet obstruction, %	0.3	0.6	0.3	0.5	0.4	.005
Paralysis, %	1.2	0.9	1.5	1.2	1.1	.04
Other neurogenic bladder, %	0.2	0.0	0.1	0.3	0.2	< .001
Multiple sclerosis, %	0.1	0.0	0.2	0.3	0.1	< .001
Prostate disease, %	2.3	2.6	2.2	2.4	2.4	.41
Any diagnosis justifying urinary catheter, %	5.5	5.4	5.8	6.7	5.8	.003
Adapted from Wald HL, Ma A, Bratzler DW, et al. Indwelling urinary catheter use in the postoperative period. *Arch Surg*2008;143(6):553.						

Intermittent catheterization is the preferred method of bladder management in this patient population.[50]

Although intermittent catheterization has a low infection rate, it does have other risks such as hematuria, urethral trauma, urethral structure, and epididymitis. Screening for UTIs in patients with spinal cord injuries is not recommended, as there is a high rate of asymptomatic bacteriuria and no demonstrable benefit in treatment without symptoms. The use of antibiotics in this patient population has only limited success, and treatment in this patient population is controversial. Treatment consists of 10 to 14 days of fluoroquinolones guided by culture and sensitivity when a symptomatic UTI is present.[49]

INFECTION PREVENTION STRATEGIES FOR CATHETER-ASSOCIATED URINARY TRACT INFECTIONS

Guidelines and guidance documents have been developed on infection prevention strategies to prevent the subset of UTIs that are associated with catheter use in healthcare settings.

SHEA/IDSA Practice Recommendation: Strategies to Prevent Catheter-associated Urinary Tract Infections in Acute Care Hospitals[32]

Strategies include:

- Appropriate infrastructure for preventing CAUTI
- Surveillance of CAUTI
- Education and training
- Appropriate technique for catheter insertion
- Appropriate management of indwelling catheters
- Accountability
- Performance measures

Association for Professionals in Infection Control and Epidemiology Guide to the Elimination of Catheter-associated Urinary Tract Infections (2008)[50]

This publication provides guidance, tools, and strategies that can be used in both acute and LTC settings.

The role of the infection preventionist in efforts to reduce the incidence of CAUTI includes policy and best practice subject matter expertise, provision of surveillance data and risk assessment, consultation on infection prevention interventions, and facilitation of CAUTI-related improvement projects. It is important that the infection preventionist communicates and networks with all members of the patient care team regarding CAUTI-related infection prevention.

Providing subject matter expertise to those involved with clinical management of the patients/residents, including physicians, physician assistants, and nurse practitioners, is essential. An understanding of the elements of surveillance definitions, compared to primary or secondary diagnoses and complications, is essential for appropriate documentation and coding.

Direct patient/resident care personnel are responsible for insertion, care, and maintenance of indwelling catheters. Therefore, success of a prevention project requires that these personnel be fully engaged and committed to this important patient safety initiative. Obtaining the resources that will engage direct care providers in CAUTI quality/performance improvement activities is a critical component of intervention development. Key players must be held accountable for compliance with the intervention. This can be facilitated through monitoring and reporting of the results of the intervention on a consistent basis, and instituting additional improvements when appropriate.[51]

Institute for Healthcare Improvement[51]

The Institute for Healthcare Improvement (IHI) *How-to Guide*focuses on four components of care:

1. Avoid unnecessary urinary catheters.
2. Insert urinary catheters using aseptic techniques.
3. Maintain urinary catheters based on recommended guidelines.
4. Review catheter necessity daily and remove promptly.

These four component areas are widely accepted as the best methods to reduce the incidence of CAUTIs. They require a multidisciplinary team approach involving physicians, nurses, facility management, and experts in infection prevention and urology. This guideline can be used to establish a teamwork framework to address the use of this device at all levels of care.[51]

Bundle Approach to Managing Urinary Catheters

With mandatory reporting of infections in healthcare and recent changes in compensation to hospitals for "never events," hospitals have developed strategies to manage the use of indwelling urinary catheters. Prior to this, the insertion of an indwelling urinary catheter was almost a "rite of passage" when one entered the hospital. A number of organizations have noted significant reductions in CAUTIs with the implementation of this strategy. One such bundle is the bladder bundle developed by Saint and colleagues.[52]

Bladder bundle:

- Aseptic insertion and proper maintenance is paramount.

- Bladder ultrasound may avoid indwelling catheterization.
- Use a condom or intermittent catheterization in appropriate patients.
- Do not use the indwelling catheter unless you must!
- Early removal of the catheter using reminders or stop orders appears warranted.

There is a growing body of evidence that simple acts such as appropriately determining who should and should not have this device can impact the number of catheter days. Cornia and colleagues suggest, "when in doubt, pull it out" to manage overuse of this device.[53]

Consideration of other devices to manage urinary output is being stressed by Saint and colleagues as a method of reducing bacteriuria, symptomatic CAUTI, and death associated with indwelling urinary catheters.[54]Suggested methods to reduce inappropriate use include computerized order entry forms where justification of use is required.[55]Nurse-driven protocols for the removal of catheters when they are no longer needed may have a greater effect in the decreased use of these devices. Coupled with awareness campaigns that these devices are not benign and that every patient has the right to a safe hospital environment, and the ready availability of other materials and/or devices (i.e., good-quality under bed pads, diapers, and condom catheters) for use, bundling activities can improve patient outcomes.

Device Removal Protocols

Automatic stop orders for indwelling urinary catheters decreases the frequency of inappropriate use and total days of device use, but may not reduce the rate of CAUTIs.[55]Early removal of indwelling devices was identified as a consistent risk for post-catheterization voiding problems; however, more study is needed to confirm this finding.[56]It appears that it is more important to develop appropriate guidelines on proper identification of candidates for indwelling catheterization followed by appropriate utilization than to simply rely on early removal of the indwelling device to correct infection risks from these devices.

Patient care providers have perceptions of risk of "never events" for their patients. A patient fall, for example, is an "all effort to avoid" risk event for caregivers. The "worse" the outcome of the event, the higher the priority the staff will give the event. Thus, if inserting an indwelling catheter will prevent a fall in the perception of the staff, the risk implied by the fall will outweigh the risk from the device. The catheter will be inserted and justified by the staff even if another method of managing the patient's voiding needs existed. Harrod et al. state, "How work gets prioritized is dependent on various factors including perceived compatibilities between patient safety initiatives and perceived risks of doing these initiatives."[57]

Surveillance Criteria for Symptomatic Catheter-associated Urinary Tract Infections

Revised criteria for surveillance of CAUTIs were released in March 2009 from NHSN. These new criteria attempt to clarify longstanding controversies about time intervals between catheter insertion and onset of infection and unclear areas in regard to age, dwell time of the catheter, and symptomatology. The category of Asymptomatic Bacteriuria was removed and a new category of Asymptomatic Bacteremic UTI was added. For a full explanation of the surveillance definitions, the reader is referred to the CDC NHSN website, Patient Safety Component, Device-associated Module for CAUTI.

Conclusions

Females of any age, diabetics, debilitated individuals, and males over the age of 50 have the highest risk for the development of UTIs. UTIs are the second most common bacterial infection seen in the outpatient setting. While usually considered a benign infection, in certain patient populations, these infections pose a risk for development of serious secondary or ascending infection.

Instrumentation of the urinary tract and especially the bladder is a risk for developing a UTI. Instrumentation coupled with prior history of a UTI, gender, age, and diabetes challenges the healthcare establishment to prevent these infections. Not all HAIs can be prevented, but more appropriate management of treatment options can be achieved.

Future Trends

IMPROVED ANTIBIOTIC USAGE

Trimethoprim-sulfamethoxazole has been the mainstay of therapy for acute cystitis. However, *E. coli* resistance rates approaching 20 percent of isolates have been identified in several regions of the United States. This has led to the increased prescription of nitrofurantoin and fluoroquinolones causing concern about resistance rates for these agents.

Assessments of potential causes and outcomes of asymptomatic bacteriuria need to occur in all levels of patient care. Evidence-based guidelines have been established by IDSA that clarify appropriate treatment. These guidelines state that there is "no measurable benefit to screen for or provide antibiotic treatment of asymptomatic bacteriuria in the following patients: premenopausal women who are not pregnant, patients with diabetes, older patients living in the community and in LTC facilities, and patients with spinal cord injury or indwelling catheters."[32] To further appropriate antibiotic usage, national trending efforts need to be initiated. Patients with indwelling urinary catheters, especially when catheterization is long term, may develop asymptomatic bacteriuria that should not be treated. Therefore, the true focus of CAUTI prevention must relate to prevention and appropriate treatment of symptomatic urinary catheter infections. Emphasis needs to be placed on management of resistant organisms and opportunist fungi.

Leis and colleagues addressed the growing issue of urine cultures being ordered without clinical indications and treatment initiated following receipt of culture results. Their findings in the two teaching hospitals under study indicated that this led to unnecessary therapy in more than 50 percent of the patients cultured. Leis proposes, "no longer routinely reporting positive urine culture results for noncatheterized inpatients should be evaluated as a quality improvement strategy."[58]

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Intravascular Device Infection

Author(s): Christopher J. Crnich, MD
Assistant Professor of Medicine

Section of Infectious Diseases
University of Wisconsin Medical School
Infection Control Department
Center for Trauma and Life Support
University of Wisconsin Hospital and Clinics
Madison, WI

Dennis G. Maki, MD
Ovid O. Meyer Professor of Medicine

Section of Infectious Diseases
University of Wisconsin Medical School
Infection Control Department
Center for Trauma and Life Support
University of Wisconsin Hospital and Clinics
Madison, WI

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Abstract

Intravascular device-associated bloodstream infections are largely avoidable. The goal must not be simply to identify and treat these infections, but rather to prevent them. During the past two decades, much has been learned about the pathogenesis and epidemiology of infections associated with intravascular devices. By drawing upon existent knowledge of the pathogenesis and epidemiology of intravascular device-associated bloodstream infections, rational and effective guidelines for their prevention can be formulated.

Key Concepts

• Prospective studies show that every type of intravascular device carries some risk of causing bloodstream infection; however, the magnitude of risk varies greatly, depending on the type of device.

• There are two major sources of intravascular device-associated bloodstream infection: (1) colonization of the intravenous device, or *catheter-associated infection*, and (2) contamination of the fluid administered through the device, or *infusate-associated infection*. Contaminated infusate is the cause of most *epidemic*intravascular device-associated bloodstream infections. In contrast, catheter-associated infections are responsible for most *endemic*intravascular device-associated bloodstream infections.

• Intravascular devices are associated with both local and systemic infection.

• When obtaining blood cultures to guide antimicrobial therapy, it is essential to use sound infection prevention and laboratory practices, including attention to skin disinfection, collection of an adequate amount of blood, and careful handling of the specimen.

• Recent studies have shown that consistent application of high-yield preventive interventions ("bundles") can lead to substantial and sustained reductions in facility rates of intravascular device-associated bloodstream infections.

• Once systems-based practices have been maximized, the judicious use of novel technologies, such as anti-infective catheters, antiseptic dressings, and antibiotic lock solutions, can promote further reductions in rates of intravascular device-associated bloodstream infections.

Background

Obtaining and maintaining reliable vascular access has become one of the most essential features of modern medical care. Unfortunately, vascular access is associated with substantial and generally underappreciated potential for producing iatrogenic disease, particularly bloodstream infection (BSI) originating from infection of the percutaneous device used for vascular access. Nearly 40 percent of all healthcare-associated bacteremias derive from vascular access in some form,[1]and it is estimated that more than 250,000 intravenous device-associated (IVDA) BSIs occur in the United States each year.[2,3] Studies performed a decade ago found that IVDA BSIs were associated with excess attributable mortality approaching 35 percent.[4,5]In contrast, more recent case control studies have failed to identify excess mortality caused by IVDA BSI.[6,7,8,9]Nevertheless, every study examining the impact of IVDA BSI on patient outcomes has found that they are associated with increased length of hospitalization and excess healthcare costs.[4,5,6,7,10]Therefore, there is a strong financial impetus for hospitals and caregivers to focus attention on this healthcare-associated complication.

Basic Principles

EPIDEMIOLOGY OF CANNULA-ASSOCIATED INFECTION

Prospective studies in which every attempt was made to conclusively identify the presence of an IVDA BSI show that every type of intravenous device (IVD) carries some risk of causing BSI; however, the magnitude of risk varies greatly, depending on the type of device (Table 34-1).[11]Historically, rates of IVDA BSIs have been expressed exclusively as BSIs per 100 devices, or percent of devices studied.

Currently, the Centers for Disease Control and Prevention (CDC) and The Joint Commission recommend that the risk of IVDA BSIs be expressed as BSIs per 1,000 IVD days.[12,13] Table 34-1 provides the rationale as to why this method of measurement is preferable. For example, expressing the risk of IVDA BSI as a function of BSIs per 100 devices (percentage of devices infected) would lead one to conclude that surgically implanted, cuffed central venous catheters (CVCs) are more hazardous (22.5 BSIs per 100 catheters) than standard nonmedicated, noncuffed CVCs (4.4 BSIs per 100 catheters). However, when risk is expressed as BSIs per 1,000 IVD days, cuffed and tunneled catheters pose substantially less risk of IVDA BSI (1.6 per 1,000 IVD days) than do standard nonmedicated, noncuffed CVCs (2.7 per 1,000 IVD days). The importance of measuring rates of infection by BSIs per 1,000 IVD days cannot be understated because the measurement takes into account the cumulative risk of infection that occurs for a particular IVD during the time it remains in use. Thus, although surgically implanted Hickman catheters develop more infections when taken as a percentage of devices used, they do so because they are used for much longer periods of time. Use of standard noncuffed, nontunneled CVCs in the same manner would most likely result in a much higher percentage of devices becoming infected.

Table 34-1 Rates of Bloodstream Infection Caused by Various Types of Devices Used for Vascular Access

Device (Number of Prospective Studies)	Rates of Device-associated BSI			
	Per 100 Catheters		Per 1,000 Catheter Days	
	Pooled Mean	95 percent CI	Pooled Mean	95 percent CI
Peripheral venous catheters (10)	0.1	0.1 to 0.2	0.5	0.2 to 0.7
Arterial catheters (14)	0.8	0.6 to 1.1	1.7	1.2 to 2.3
Short-term, nonmedicated CVCs (79)	4.4	4.1 to 4.6	2.7	2.6 to 2.9
Pulmonary artery catheters (13)	1.5	0.9 to 2.0	3.7	2.6 to 5.0
Hemodialysis catheters Noncuffed (16) Cuffed (16)	 8.0 21.2	 7.0 to 9.0 19.7 to 22.8	 4.8 1.6	 4.2 to 5.3 1.5 to 1.7
Peripherally inserted central catheters (15)	3.1	2.6 to 3.7	1.1	0.9 to 1.3

Long-term tunneled and cuffed CVCs (29)	22.5	21.2 to 23.7	1.6	1.5 to 1.7
Subcutaneous central venous ports (14)	3.6	2.9 to 4.3	0.1	0.0 to 0.1

CVCs, central venous catheters.

Adapted from Maki DG, Kluger DM, Crnich CJ. The risk of bloodstream infection in adults with different intravascular devices: a systematic review of 200 published prospective studies. *Mayo Clin Proc*2006;81(9):1159–1171.

In recent years, the factors associated with an increased risk of IVDA BSI have become better delineated (Table 34-2). Prolonged hospitalization and severity of illness clearly influence the risk of IVDA BSI, and clinical states such as neutropenia,[14,15] acquired immunodeficiency syndrome (AIDS),[16,17] and bone marrow transplantation[18] have been associated with four- to sixfold increases in rates of IVDA BSI. However, the features of the IVD (Table 34-1), its insertion, and its maintenance appear to have far greater impact on the overall risk of infection. For example, short-term use, noncuffed CVCs have rates of catheter-associated BSI in the range of 3 to 5 percent (2 to 3 per 1,000 IVD days).[11] Far lower rates of infection have been encountered with surgically implanted cuffed Hickman or Broviac catheters and subcutaneous central venous ports (1.6 and 0.1 per 1,000 IVD days, respectively).[11] Studies of peripherally inserted central catheters (PICCs) have found that they are associated with a lower risk of IVDA BSI. However, most of these studies were performed in the outpatient setting, and recent hospital-based studies have found that these devices are associated with a risk of IVDA BSI that approaches that seen with noncuffed, multilumen CVCs (approximately 2.1 per 1,000 IVD days).[19]

Table 34-2 Risk Factors for Intravascular Device-associated Bloodstream Infection With Short-term Intravascular Devices

Risk Factors (Number of Studies)	Relative Risk or Odds Ratio

Underlying disease:	4.8
AIDS (2)	1.0 to 15.1
Neutropenia (2)	2.4
Gastrointestinal disease (1)	4.4
Surgical service (1)	0.4 to 6.7
ICU/CCU placement (3)	1.0 to 6.7
Extended hospitalization (3)	1.0 to 3.8
Other intravascular devices (2)	0.1 to 0.5
Systemic antibiotics (3)	8.7 to 9.2
Active infection at another site (2)	4.2
High APACHE III score (1)	2.0 to 2.5
Mechanical ventilation (1)	2.6
Transplant patient (1)	

Features of Insertion

Difficult insertion (1)	5.4
Maximal sterile barriers (1)	0.2
Tunneling (2)	0.3 to 1.0
Insertion over a guidewire (8)	1.0 to 3.3
Insertion site:	1.0 to 3.3
Internal jugular vein (6)	0.4 to 1.0
Subclavian vein (5)	3.3 to 4.8
Femoral vein (2)	1.0
Defatting insertion site (1)	1.0 to 6.5
Use of a multilumen catheter (8)	

Catheter Management

Routine change of IV set (2)	1.0
Staffing in SICU (nurse:patient ratio) (1)	61.5
1:2.0	15.6
1:1.5	4.0
1:1.2	1.0
1:1	5.3
Inappropriate catheter usage (1)	1.0 to 8.7
Duration of catheterization >7 days (5)	17.9 to 44.1
Colonization of catheter hub (3)	1.0 to 4.8
Parenteral nutrition (2)	

CCU, coronary care unit; ICU, intensive care unit; SICU, surgical intensive care unit.

Adapted from Safdar N, Kluger DM, Maki DG. A review of risk factors for catheter-related bloodstream infection caused by percutaneously inserted, noncuffed central venous catheters: implications for preventive strategies. *Medicine*2002;81(6):466–479.

In 289 patients, Merrer et al. found that insertion of an IVD in the femoral versus the subclavian vein was associated with a greatly increased risk of infection (20.0 versus 3.7 BSIs per 1,000 IVD days; $p<.001$) and thrombotic complications (21.5 percent versus 1.9 percent; $p<.001$),[20]a finding that has been corroborated by more recent observational studies.[21,22]Moreover, Robert et al. found that patients with primary BSI were more likely to have received care during times when there was a lower nurse-to-patient ratio and a higher proportion of "float" staff, rather than dedicated nursing staff.[23]

PATHOGENESIS OF INTRAVASCULAR DEVICE-ASSOCIATED SEPSIS

There are two major sources of IVDA BSI: (1) colonization of the IVD, or *catheter-associated infection*, and (2) contamination of the fluid administered through the device, or *infusate-associated infection*.[2]

Contaminated infusate is the cause of most *epidemic*IVDA BSIs. In contrast, catheter-associated infections are responsible for most *endemic*IVDA BSIs.[1]

For microorganisms to cause catheter-associated infection, they must first gain access to the extraluminal or intraluminal surface of the device, where they can adhere, produce, and subsequently become incorporated into a biofilm that allows sustained infection and hematogenous dissemination.[24]

Microorganisms gain access to the bloodstream by one of three mechanisms (Figure 34-1): (1) skin organisms invade the percutaneous tract, probably facilitated by capillary action, at the time of insertion or in the days following; (2) microorganisms contaminate the catheter hub (and lumen) when the catheter is inserted over a percutaneous guidewire or later manipulated; or (3) organisms are carried hematogenously to the implanted IVD from remote sources of local infection, such as a pneumonia.

With *short-term*IVDs (in place < 10 days), such as peripheral intravenous (IV) catheters, arterial catheters, and noncuffed, nontunneled CVCs, most device-associated BSIs are of cutaneous origin, from the insertion site, and gain access extraluminally, occasionally intraluminally.[25,26,27,28]In contrast,

contamination of the catheter hub and luminal fluid is the predominant mode of BSI with *long-term*IVDs (e.g., in place > 10 days), such as cuffed Hickman- and Broviac-type catheters, subcutaneous central ports, and PICCs.[29,30,31]

It is important to recognize that infusate (parenteral fluid, blood products, or IV medications) administered through an IVD can also become contaminated and produce device-associated BSI. Contaminated fluid is fortunately an uncommon cause of endemic infusion-associated infection with most short-term IVDs; however, it is an important cause of BSIs with arterial catheters used for hemodynamic monitoring and long-term IVDs, such as Hickman or Broviac catheters, cuffed hemodialysis CVCs, and subcutaneous central venous ports.[28,32,33]

Most healthcare-associated *epidemics*of infusion-associated BSI have been traced to contamination of infusate by Gram-negative bacilli, introduced during its manufacture (intrinsic contamination) or during its preparation and administration in the healthcare setting (extrinsic contamination).[34,35]If an epidemic is suspected, the epidemiologic approach must be methodical and thorough, yet expeditious, directed toward establishing the bona fide nature of the putative epidemic infections (i.e., ruling out "pseudoinfections")[36]and confirming the existence of an epidemic; defining the reservoirs and modes of transmission of the epidemic pathogens; and, most importantly, controlling the epidemic quickly and completely (Table 34-3). Control measures are predicated upon accurate delineation of the epidemiology of the epidemic pathogen. The essential steps in dealing with a suspected healthcare-associated outbreak have recently been reviewed.[2]

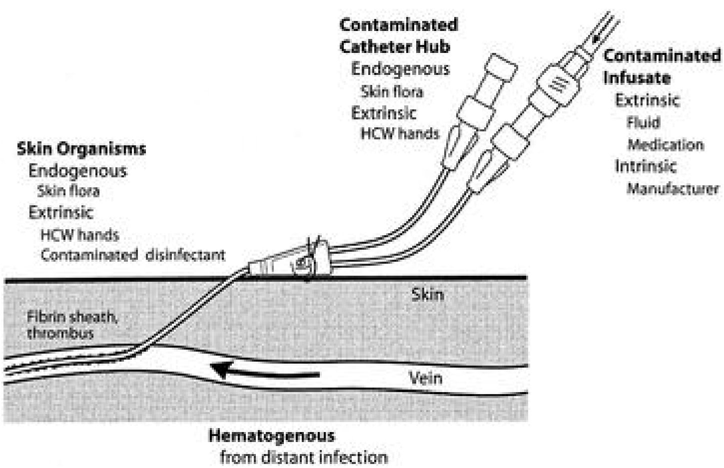

Figure 34-1.

Potential sources of infection of a percutaneous IVD: the contiguous skin flora, contamination of the catheter hub and lumen, contamination of infusate, and hematogenous colonization of the IVD from distant, unrelated sites of infection. (From Crnich CJ, Maki DG. The promise of novel technology for the prevention of intravascular device-related bloodstream infection. I. Pathogenesis and short-term devices. *Clin Infect Dis*2002;34(9 View Image

Table 34-3 Approach to Suspected Epidemic Healthcare-Associated Bloodstream Infections

Administrative preparation:

1. The infection control committee or a similarly designated body should be responsible for investigating a suspected epidemic.

a. When an epidemic is suspected, a single person (e.g., the hospital epidemiologist) should be designated to direct the investigation.

b. The necessary disciplines, such as the involved department or departments, pharmacy, nursing, hospital administration, and employee health, should be identified and involved at the outset of the investigation.

c. All major decisions should be made in conjunction with the investigating team, attending staff, and administration.

d. All information released to the public should be cleared through the hospital epidemiologist and hospital administration.

2. Retrieve putative epidemic isolates:

a. Retrieve all available laboratory isolates of the epidemic strain(s) as soon as possible for further characterization and possible molecular subtyping.

b. Laboratory personnel should retain unusual organisms that are being encountered on an increasing basis as a matter of routine.

3. Preliminary actions:

a. Identify and characterize individual cases.

- Make an epidemic-case definition.

- Confirm that each suspected case-patient has true BSI and not pseudo-BSI (i.e., patient has clinical signs of infection such as fever, chills, hypotension).

- Confirm the concordance of isolates from the patient's blood and IVDs or infusate (if applicable) down to the molecular level.

b. Ascertain if the situation represents an epidemic and not a pseudoepidemic by showing an increased prevalence of cases with the epidemic strain compared with baseline surveillance rates during the same interval.

c. Implement provisional measures.

- Preliminary screening of case-patient's environment and those involved in care, guided by the ecology and epidemiology of the epidemic strain.

- Implement preliminary control measures, based on the initial suspected source of infection (e.g., change infusion sets every 24 hours during a suspected outbreak of infusate-associated BSI).

d. Intensify surveillance hospitalwide.

e. Review general infection prevention policies to identify any changes or breaks with these policies.

f. Determine the need for extramural assistance (i.e., local and national health authorities).

4. Epidemiologic investigations:

a. Clinical-epidemiologic studies

- Identify the population at greatest risk.

- Perform a retrospective case-control study to point up risk factors or potential sources.

b. Microbiologic studies

- Focus studies of the inanimate environment and medical personnel, if indicated, based on the results of the case-control study.

- Blind large-scale culturing of the hospital environment or medical personnel is discouraged because it is expensive and often of limited value. Such studies are better guided by the results of the epidemiological investigation.

c. Definitive control measures:

- Remove the probable sources or correct breaks in infection prevention practices.

- If intrinsic contamination of a commercial product is suspected or, especially, proven, state and local health authorities, the U.S. Food and Drug Administration, the Centers for Disease Control and Prevention, and the manufacturer should be immediately informed. Remaining supplies of the suspect product should be quarantined and retained for further investigation, possibly by public health or regulatory authorities.

d. Report the findings

BSI, bloodstream infection; IVD, intravascular device.

Adapted from Maki DG. Epidemic nosocomial bacteremias. In: Wenzel RP, ed. *Handbook of Hospital Acquired Infections*. Boca Raton, FL: CRC Press, 1981:371–512.

Microbiology

Figure 34-2 summarizes the microbial profile of IVDA BSI from 159 published prospective studies.[37] As might be expected from knowledge of the pathogenesis of these infections, skin microorganisms account for the largest proportion of IVDA BSIs.

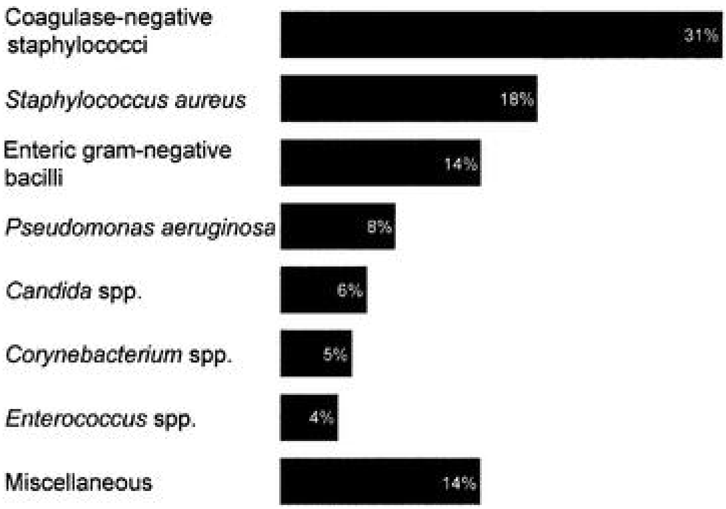

Figure 34-2.

Microbial profile of IVDA BSI based on an analysis of 159 published prospective studies. (From Maki DG, Kluger DM, Crnich CJ. The microbiology of intravascular device-related infection in adults: 1. an analysis of 159 prospective studies; 2. implications for prevention and treatment [abstract]. Abstracts and Proceedings from the 40th Annual Meeting of the Infectious Disease Society of America. Chicago, IL: Infectious Disease Society of America, 2002.)

View Image

Definitions For Infusion-Associated Infection

IVDs are associated with both local and systemic infection. The CDC has published definitions for laboratory-confirmed BSI (Table 34-4).[38] These definitions are useful for the purposes of surveillance but rely heavily upon the construct, CVC-associated BSI, which implicitly assumes that every primary BSI originates from a CVC. This practice results in an overestimate of the true risk of CVC-associated infection because not all primary BSIs originate from a central venous device; some are secondary BSIs deriving from unrecognized postoperative surgical site or intra-abdominal infections or healthcare-associated pneumonias, or originate from other vascular devices, such as peripheral venous or, especially, arterial catheters used for hemodynamic monitoring.

By applying molecular subtyping techniques[39,40,41] to the results of semiquantitative or quantitative cultures of the removed IVD and hub or the results of cultures of blood drawn through the IVD and a separate peripheral blood sample, it is now possible to reliably implicate an IVD as the source of a healthcare-associated BSI. Using these criteria allows formulation of simple but more rigorous definitions for IVDA infection (Table 34-5), which the authors believe bear consideration as a standard for randomized trials and studies of risk factors for IVDA infection.

Table 34-4 Centers for Disease Control and Prevention Definitions for Laboratory-confirmed Bloodstream Infection

Primary Bloodstream Infection

Must meet at least one of the following criteria:

*Criterion 1:*Patient has a recognized pathogen cultured from one or more blood cultures *and*the pathogen cultured is not related to an infection at another site. (See Notes 1 and 2.)

*Criterion 2:*Patient has at least one of the following signs and symptoms: fever (>38°C), chills, or hypotension *and*signs *and*symptoms and positive laboratory results are not related to an infection at another site and a common skin contaminant (e.g., diphtheroids [*Corynebacterium*spp.], *Bacillus*spp., *Propionibacterium*spp., coagulase-negative staphylococci, viridans group streptococci, *Aerococcus*spp., *Micrococcus*spp.) is cultured from two or more blood cultures drawn on separate occasions. (See Notes 3 and 4.)

*Criterion 3:*A patient 12 months of age or younger who has at least one of the following signs or symptoms: fever (<38°C, rectal), hypothermia (>37°C, rectal), apnea, or bradycardia *and*signs and symptoms are not related to an infection at another site and a common skin contaminant (e.g., diphtheroids [*Corynebacterium*spp.], *Bacillus*spp., *Propionibacterium*spp., coagulase-negative staphylococci, viridans group streptococci, *Aerococcus*spp., *Micrococcus*spp.) is cultured from two or more blood cultures drawn on separate occasions. (See Notes 3 and 4.)

Note 1.In criterion 1, the phrase "one or more blood cultures" means that at least one bottle from a blood draw is reported by the laboratory as having grown organisms (i.e., is a positive blood culture).

Note 2.In criterion 1, the term "recognized pathogen" does not include organisms considered common skin contaminants (see criteria 2 and 3 for a list of common skin contaminants). A few of the recognized pathogens are *Staphylococcus aureus*, *Enterococcus*spp., *Escherichia coli*, *Pseudomonas*spp., *Klebsiella*spp., and *Candida*spp.

Note 3.In criteria 2 and 3, the phrase "two or more blood cultures drawn on separate occasions" means (1) that blood from at least two blood draws collected within 2 days of each other (e.g., blood draws on Monday and Tuesday or Monday and Wednesday would be acceptable for blood cultures drawn on separate occasions, but blood draws on Monday and Thursday would be too far apart in time to meet this criterion) and (2) that at least one bottle from each blood draw is reported by the laboratory as having grown the same common skin contaminant organism (i.e., is a positive blood culture). (See Note 4 for determining sameness of organisms.)

Note 4.There are several issues to consider when determining sameness of organisms.

a. If the common skin contaminant is identified to the species level from one culture and a companion culture is identified with only a descriptive name (i.e., to the genus level), then it is assumed that the organisms are the same. The speciated organism should be reported as the infecting pathogen.

b. If common skin contaminant organisms from the cultures are speciated but no antibiograms are done or they are done for only one of the isolates, it is assumed that the organisms are the same.

c. If the common skin contaminants from the cultures have antibiograms that are different for two or more antimicrobial agents, it is assumed that the organisms are not the same.

d. For the purpose of National Healthcare Safety Network antibiogram reporting, the category interpretation of intermediate (I) should not be used to distinguish whether two organisms are the same.

From Horan TC, Andrus M, Dudeck MA. CDC/NHSN surveillance definition of health care-associated infection and criteria for specific types of infections in the acute care setting. *Am J Infect Control*2008;36(5):309–332.

Table 34-5 Proposed Definitions for Intravascular Device-associated Colonization, Local Infection, and Bloodstream Infection Based on Microbiologic Confirmation of the Intravascular Device as the Source

IVD colonization	(i) A positive semiquantitative* (or quantitative**) culture of the implanted portion or portions of the IVD; (ii) absence of signs of local or systemic infection.
Local IVD infection	(i) A positive semiquantitative* (or quantitative**) culture of the removed IVD or a positive microscopic examination or culture of pus or thrombus from the cannulated vessel; (ii) clinical evidence of infection of the insertion site (i.e., erythema, induration, or purulence); but (iii) absence of systemic signs of infection and negative blood cultures, if done.
IVDA BSI	*If the IVD is removed:*

	(i) A positive semiquantitative* (or quantitative**) culture of the IVD or a positive culture of the catheter hub or infusate (or positive microscopic examination or culture of pus or thrombus from the cannulated vessel) and one or more positive blood cultures, ideally percutaneously drawn, concordant for the same species, ideally by molecular subtyping methods; (ii) clinical and microbiologic data disclose no other clear-cut source for the BSI.
	If the IVD is retained:
	(i) If quantitative blood cultures are available, cultures drawn both from the IVD and a peripheral vein (or another IVD) are both positive and show a marked step-up in quantitative positivity (fivefold) in the IVD-drawn culture; (ii) clinical and microbiologic data disclose no other clear-cut source for the BSI.
	or
	(i) If automated monitoring of incubating blood cultures is available, blood cultures drawn concomitantly from the IVD and a peripheral vein (or another IVD) show both are positive, but the IVD-drawn blood culture turns positive more than 2 hours before the peripherally drawn culture; (ii) clinical and microbiologic data disclose no other clear-cut source for the BSI.

*Roll plate of cannula segment(s) >15 colony-forming units (cfu).

**Sonication culture of cannula segment(s) ≥10^3cfu.

BSI, bloodstream infection; IVD, intravascular device; IVDA, intravascular device-associated.

Adapted from Crnich CJ, Maki DG. The role of intravascular devices in sepsis. *Curr Infect Dis Rep*2001;3(6):497–506.

Diagnosis of Infusion-Associated Septicemia

CLINICAL FEATURES

Recent evidence-based guidelines provide the best current information on the evaluation of the patient in an intensive care unit (ICU) with fever or other signs of sepsis.[42]Before any decision regarding initiation of antimicrobial therapy or removal of an IVD, the patient must be thoroughly examined to identify all plausible sites of infection, including ventilator-associated pneumonia, catheter-associated urinary tract infection, surgical site infection, antibiotic-associated colitis, or line sepsis.

Despite the challenge of identifying the source of a patient's signs of sepsis,[42]several clinical, epidemiologic, and microbiologic findings point strongly toward an IVD as the source of a septic episode (Table 34-6).[2,43]Patients with abrupt onset of signs and symptoms of sepsis without any other identifiable source should prompt suspicion of infection of an IVD. The presence of inflammation or purulence at the catheter insertion site is now uncommon in patients with IVDA BSI.[44]However, if purulence is seen in combination with signs and symptoms of sepsis, it is highly likely the patient has IVDA BSI, which should prompt removal of the IVD. Finally, recovery of certain microorganisms in multiple blood cultures, such

as staphylococci, *Corynebacterium*or *Bacillus*species, or *Candida*or *Malassezia*species strongly suggests infection of the IVD.

Table 34-6 Clinical, Epidemiologic, and Microbiologic Features of Intravascular Device-Associated Bloodstream Infection

Nonspecific	Suggestive of Device-Associated Etiology
Fever	Patient unlikely candidate for sepsis (e.g., young, no underlying diseases)
Chills, shaking rigors[a]	Source of sepsis inapparent, no identifiable local infection
Hypotension, shock[a]	Intravascular device in place, especially central venous catheter
Hyperventilation, respiratory failure	Inflammation or purulence at insertion site
Gastrointestinal[a]	Abrupt onset, associated with shock
Abdominal pain	Septicemia caused by staphylococci (especially coagulase-negative staphylococci) or *Corynebacterium*, *Candida*, *Trichophyton*, *Fusarium*, or *Malassezia*species[b]
Vomiting	Very high-grade (>25 cfu/mL) candidemia
Diarrhea	Cluster of cryptogenic infusion-associated bloodstream infections caused by *Enterobacter cloacae*, *Pantoea agglomerans*, or *Serratia marcescens*[b]
Neurologic[a]	Sepsis refractory to antimicrobial therapy or dramatic improvement with removal of cannula and infusion[a]
Confusion	
Seizures	

[a]Commonly seen in overwhelming Gram-negative sepsis originating from contaminated infusate,peripheral suppurative phlebitis, or septic thrombosis of a central vein.

[b]Conversely, septicemia caused by streptococci, aerobic Gram-negative bacilli, or anaerobes is unlikely to derive from an intravascular device.

Adapted from Maki D, Mermel L. Infections due to infusion therapy. In: Bennett JV, Brachman PS, eds. *Hospital Infections*, 4th ed. Philadelphia: Lippincott-Raven; 1998:689–724.

BLOOD CULTURES

It is indefensible to start anti-infective drugs for suspected or presumed infection in the critically ill patient without first obtaining blood cultures from two separate sites, *at least one of which is drawn from a peripheral vein by percutaneous venipuncture*. The volume of blood cultured is essential to maximize the sensitivity of blood cultures for diagnosis of bacteremia or candidemia: In adults, obtaining at least 20 mL, ideally 30 mL, per drawing (each specimen containing 10 mL or 15 mL, inoculated into aerobic and anaerobic media), significantly improves the yield as compared with obtaining only 5 mL at each drawing and culturing a smaller total volume.[45,46,47,48]In adults, if at least 30 mL of blood is cultured, 99 percent of detectable bacteremias should be identified.[45,46,49]Similar operating characteristics are achieved in the pediatric population using a weight-based graduated volume approach to blood cultures.[50]Standard blood cultures drawn through CVCs provide excellent sensitivity for the diagnosis of BSI but are less specific than cultures obtained from a peripheral vein.[51,52,53,54,55]If the patient has a long-term

multilumen catheter, it may be prudent to obtain a specimen from each lumen of the catheter because studies have found a high rate of discordance (~30 percent) between cultures obtained from different lumens of the same catheter.[56,57]

Every effort must be made to prevent the introduction of contamination when drawing blood cultures because a single contaminated blood culture has been shown to prolong hospitalization by 4 days and increase the costs of hospitalization by $4,100 to $4,400.[58,59] Tincture of iodine, isopropyl alcohol, chlorhexidine, or povidone-iodine combined with ethyl alcohol, rather than aqueous povidone-iodine, should be used for skin antisepsis before venipuncture for blood cultures, recognizing that studies have shown significantly reduced rates of contamination with use of these agents.[59,60,61,62,63] As many as 30 percent of blood cultures positive for coagulase-negative *Staphylococcus* represent true infection;[64,65] however, most single positive cultures represent contamination,[66] a finding that should re-emphasize the need to obtain cultures from two separate sites when BSI is suspected.

MICROBIOLOGIC ANALYSIS OF REMOVED INTRAVASCULAR DEVICES

Removal and direct culture of the IVD historically has been the method of choice for confirming the presence of IVDA BSI, particularly with IVDs of short-term use. Numerous studies have shown that culturing catheter segments semiquantitatively on solid media[25,66,67] or quantitatively in liquid media (e.g., removing the adherent organisms by sonication[68,69,70]) provides superior sensitivity and specificity for the diagnosis of IVDA BSI, with a strong correlation between high colony counts and IVDA BSI. Growth of ≥15 colony forming units (cfu) from a catheter segment by semiquantitative culture or growth of $\geq 10^3$ cfu from a catheter cultured after sonication with accompanying local inflammation or signs of sepsis indicate IVDA infection. Significant growth in the absence of local or systemic inflammation suggests colonization of the device; if continued vascular access is needed, a new device should be placed in a new location rather than replacing it with a new one in the same location by guidewire exchange.

Recent studies[70,71,72] have suggested that quantitative methods (e.g., sonication) are superior to the semiquantitative methods (e.g., roll plate), but other studies have shown them to be equivalent.[73,74] Because hub contamination progressing to intraluminal colonization is the primary route of infection for "long-term devices" (e.g., devices in place >10 days), quantitative techniques may be superior to semiquantitative techniques in detecting infections from these types of devices because they remove organisms from both the internal and external surface of catheters.[30,69,75] In contrast, semiquantitative methods may be preferred over quantitative methods in cases of suspected infection related to a "short-term device" (e.g., devices in place <10 days) because the primary route of infection in this setting is due to extraluminal spread of skin organisms at the catheter insertion site—and the semiquantitative method is simple, less expensive, and allows identification of the infecting organisms a day earlier.

Impression Gram stains[25,76,77] or acridine orange stains[78,79,80] of intravascular segments of removed catheters have shown excellent correlation with quantitative techniques for culturing catheters and may permit rapid diagnosis of catheter-associated infection.

A novel culture-brush, which can be passed down the lumen and out the end of an implanted catheter to pick up luminal biofilm and colonized fibrin and thrombus around the tip, has been developed to diagnose infections of CVCs without having to remove the catheter.[57,81,82,83] A recent prospective study

comparing the endoluminal brush to the semiquantitative methods found the brush to be 95 percent sensitive and 84 percent specific.[83] However, a prospective study by van Heerden et al. appears to call these results into question because those authors found the endoluminal brush to be only 21 percent sensitive although the specificity remained high at 100 percent.[84] A possible explanation for this discrepancy may lie in part with the fact that the latter study used the endoluminal brush method with short-term catheters (all catheters were removed between days 5 and 7 after placement), a setting in which most of the infecting organisms would be expected to have gained access extraluminally, by invasion of the percutaneous insertion tract.

Quantitative skin-swab culture of the catheter insertion site has been proposed as a simple means of detecting infection with short-term CVCs.[85,86,87,88] Studies suggest that this method is highly sensitive in identifying probable infection of the CVC, but most have not found it to be very specific. Therefore, cultures of the device insertion site can be used to rule out infection of a short-term IVD, if negative, but do not necessarily predict device infection, if positive.

To rigorously identify the mechanism of IVDA BSI in prospective studies, it is necessary to culture all potential sources at the time of catheter removal (see Figure 34-1): skin of the insertion site, each catheter hub, infusate from each lumen, as well as catheter segments. If the results of these cultures appear to link a BSI with microorganisms isolated from one or more portions of the device, efforts then need to be made to conclusively establish concordance, beyond speciation and antimicrobial susceptibility pattern, using one or more molecular subtyping systems, such as multilocus enzyme analysis, plasmid profile, or restriction-enzyme analysis of chromosomal DNA by pulsed-field electrophoresis.[40,41,47,89,90]

MICROBIOLOGIC ANALYSIS OF IMPLANTED LONG-TERM INTRAVASCULAR DEVICES

The methods described above require removal of the device for confirmation of IVDA BSI. This is often undesirable or difficult with surgically implanted IVDs, such as Hickman and Broviac catheters, cuffed and tunneled hemodialysis catheters, and subcutaneous central venous ports. Only 15 to 45 percent of long-term IVDs that are removed for suspected infection are truly colonized or infected at the time of removal.[16,68,91,92,93,94,95,96] To avoid unnecessary removal of IVDs, methods have been developed to identify infection while allowing the device to stay in place: (1) the endoluminal brush culture described already; (2) paired quantitative blood cultures drawn from the IVD and percutaneously from a peripheral vein[57,97,98]; (3) differential time to positivity (DTP) of paired standard blood cultures, one drawn from the IVD, the second from a peripheral vein[57,98,99,100,101]; and (4) Gram stain[102] or acridine orange staining (AOS) of blood samples drawn through the IVD.[96,98,103,104]

If a laboratory has available an automated quantitative system for culturing blood (e.g., Isolator lysis-centrifugation system, Wampole Laboratories, Cranbury, NJ), quantitative blood cultures drawn through the IVD and concomitantly by venipuncture from a peripheral vein (or another IVD) can permit the diagnosis of IVDA bacteremia or fungemia to be made with sensitivity and specificity of 87 and 99 percent, respectively,[98] *without* removal of the catheter, *if* empiric antimicrobial therapy has not yet been initiated. With this approach, IVD-drawn cultures demonstrating 5- to 10-fold higher microorganism counts, as compared with counts of the same microorganism obtained in a culture drawn from a peripheral vein, confirm the presence of IVDA BSI.

Quantitative blood cultures are labor intensive and cost almost twice as much as standard blood cultures. It is well known that blood culture bottles inoculated with a larger number of organisms turn positive sooner than do culture bottles inoculated with a lower number of organisms,[99,105] and the wide availability of automated radiometric blood culture systems (e.g., BACTEC system, Becton Dickinson, Franklin Lakes, NJ), in which blood cultures are continuously monitored for microbial growth, has led to a clever application of this system to take advantage of this phenomenon. The DTP of paired blood cultures, one drawn through the IVD and the second concomitantly from a peripheral vein, has been shown to reliably identify IVDA BSI of long-term IVDs if the blood culture drawn from the IVD turns positive 2 or more hours before the culture is drawn peripherally. In a recent meta-analysis of published studies, the pooled sensitivity and specificity of DTP were 85 and 83 percent, respectively.[98] The performance of DTP in short-term IVDs has recently been examined, with disappointing results,[106] a finding that is not entirely unexpected given the predominant role of extraluminal infection with these devices.

A simple, rapid, and potentially cost-effective method of detecting IVDA BSI is Gram stain[102] or AOS of a sample of lysed and centrifuged blood drawn through the suspected IVD.[103,107] In a recent prospective study of 124 adult surgical patients, this method was found to be 96 percent sensitive and 92 percent specific.[103] These same authors have shown that routine use of AOS on blood aspirated from IVDs suspected to be infected can bring significant cost savings,[104] primarily as a result of reducing unnecessary IVD removal. AOS has been shown to be of limited utility in diagnosing IVDA BSI of short-term IVDs (mean duration of catheterization 6 days), whereas AOS failed to diagnose all 12 confirmed IVDA BSIs;[96] therefore AOS will likely remain useful only for suspected infection of long-term IVDs.

DETECTION OF CONTAMINATED INFUSATE

To diagnose infection caused by contaminated infusate, a sample of IV fluid, aspirated from the line, should be cultured quantitatively and qualitatively;[108] concordance with positive peripheral blood cultures, without another identifiable source for the patient's BSI, definitively implicates infected infusate as the cause of the BSI. Anaerobic culture techniques are not necessary unless blood or another biologic product is involved.

Strategies For Prevention of Intravascular Device-Associated Bloodstream Infection

Recommendations for the prevention of IVDA BSIs were updated by the Healthcare Infection Control Practices Advisory Committee (HICPAC) in 2011.[109] Table 34-7 summarizes the HICPAC recommendations and scores each recommendation based on the quality of the available scientific evidence. In addition to following HICPAC guidelines, the Society for Healthcare Epidemiology of America (SHEA) recommended that hospitals use all-inclusive catheter kits as well as insertion checklists to ensure that all necessary equipment is present during CVC insertion and monitor compliance with recommended insertion practices.[110]

DEVICE INSERTION

Choice of Catheter and Site of Device Insertion

Obviously, the choice of IVD inserted into a patient will be guided primarily by that patient's particular needs (e.g., hemodialysis versus fluid administration). However, the astute clinician can mitigate much of the risk associated with vascular access by choosing the best device for the task at hand and inserting the IVD in a location associated with the least risk of infection. Studies have shown that multilumen IVDs are associated with a higher risk of infection than are single lumen catheters.[111] That said, if a particular patient has need for multiple infusions, it makes little sense to insert several single lumen IVDs in multiple locations, rather than a multilumen IVD in a single location.

To date, there have been no randomized studies designed to evaluate the optimal location for placement of short-term CVCs. However, the data accumulated from numerous observational studies suggest that the lowest risk of IVDA BSI is seen with subclavian vein insertion and the highest risk of IVDA BSI is seen with femoral vein insertion, with an intermediate level of risk associated with jugular vein insertions.[20,28,112,113,114,115,116,117]

The femoral vein is often used for central venous access, especially on nonsurgical services, because of the ease of cannulation and the lower risk of mechanical complications from insertion (i.e., bleeding or pneumothorax). Unfortunately, prospective studies evaluating the risk of femoral vein device placement have shown that CVCs placed in the femoral vein are much more likely to be colonized at the time of removal than are catheters placed in the internal jugular vein (relative risk [RR] ≡ 4.7; 95 percent confidence interval [CI] ≡ 2.0 to 8.8; *p*≡ .0001)[116] and are associated with an increased risk of IVDA BSI when compared with CVCs placed in the subclavian vein (4.4 percent versus 1.5 percent; *p*≡ .07).[20] Furthermore, recent prospective studies have found higher rates of IVDA deep vein thrombosis with femoral catheters, in the range of 6.6 to 25 percent.[20,118,119,120] In general, femoral vascular access should be used only if emergent access is required, the inexperience of the operator prevents placement in the upper body, or there is a contraindication to placement in the upper body (no available sites, an extensive burn, or refractory coagulopathy). If a short-term CVC must be placed in the femoral vein or artery, it is important that the catheter insertion site be located at least 2 inches (5 cm) below the inguinal crease or an intertriginous area in order to allow a more secure protective dressing to be affixed because this anatomical region is heavily colonized with bowel organisms and yeasts.

In contrast to short-term CVCs, observational studies of hemodialysis catheters have not been able to confirm a lower rate of infection with IVDs inserted in the subclavian vein compared with those inserted in the internal jugular vein,[121,122,123] although there is still excess risk associated with femoral vein placement.[124] More importantly, prospective studies of catheters used for hemodialysis have demonstrated a significant risk of great vein thrombosis and stenosis in catheters inserted into the subclavian vein that approaches 40 to 50 percent, as compared with rates of 0 to 10 percent with catheters inserted into the internal jugular vein.[125,126] Based on these data, internal jugular vein insertion is preferable to subclavian vein insertion for central access for hemodialysis.

Table 34-7 Summary of 2011 Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee Guidelines for the Prevention of Intravascular Catheter-related Infections

Recommendation	Strength of Evidence*

Education, training, and staffing	IA
Educate all healthcare personnel involved with intravascular catheter use, insertion, and maintenance.	IA
Periodically assess knowledge and adherence to guidelines.	IA
Designate only trained personnel who demonstrate competence for the insertion and maintenance of peripheral and central intravascular catheters.	IB
Ensure appropriate nurse staffing levels in ICUs where nurses are managing patients with CVCs.	

Selection of catheters and sites	II
Peripheral catheters and midline catheters	II
In adults, use an upper extremity site for catheter insertion. Replace a catheter inserted in a lower extremity site to an upper extremity site as soon as possible.	IB
	IA
In pediatric patients, the upper or lower extremities or the scalp (in neonates or young infants) can be used.	
	II
Select catheters on the basis of intended purpose and duration of use, known infectious and noninfectious complications and experience of individual catheter operators.	
	II
Avoid the use of steel needles for the administration of fluids and medication that might cause tissue necrosis if extravasation occurs.	IB
	IA
Use a midline catheter or PICC instead of a short peripheral catheter when the duration of IV therapy will likely exceed 6 days.	
	IA
Evaluate the catheter insertion site daily by palpation through the dressing to discern tenderness and by inspection if a transparent dressing is in use. Gauze and opaque dressings should not be removed if the patient has no clinical signs of infection. If the patient has local tenderness or other signs of possible CRBSI, an opaque dressing should be removed and the site inspected visually.	IB
	Unresolved
	IA
Remove peripheral venous catheters if the patient develops signs of phlebitis, infection, or a malfunctioning catheter.	IA
	IB
Central venous catheters	
Weigh the risks and benefits of placing a central venous device at a recommended site to reduce infectious complications against the risk for mechanical complications.	IB
	Unresolved
Avoid using the femoral vein for central venous access in adult patients.	IA
Use a subclavian site, rather than a jugular or femoral site, in adult patients to minimize infection risk for nontunneled CVC placement.	IB
No recommendation can be made for a preferred site of insertion to minimize infection risk for a tunneled CVC.	
Avoid the subclavian site in hemodialysis patients and patients with advanced kidney disease, to avoid subclavian vein stenosis.	
Use a fistula or graft in patients with chronic renal failure instead of a CVC for permanent access for dialysis.	
Use ultrasound guidance to place CVCs (if technology is available) to reduce the number of cannulation attempts and mechanical complications. Ultrasound guidance should only be used by those fully trained in its technique.	
Use a CVC with the minimum number of ports or lumens essential for the management of the patient.	
No recommendation can be made regarding the use of a designated lumen for parenteral nutrition.	
Promptly remove any intravascular catheter that is no longer essential.	
When adherence to aseptic technique cannot be ensured (i.e., catheters inserted during a medical emergency), replace the catheter as soon as possible (i.e., within 48 hours).	

Hand hygiene and aseptic technique Perform hand hygiene before and after palpating catheter insertion sites as well as before and after inserting, replacing, accessing, repairing, or dressing an IV catheter. Palpation of the insertion site should not be performed after the application of antiseptic, unless aseptic technique is maintained. Maintain aseptic technique for the insertion and care of intravascular devices. Wear clean gloves for insertion and care of peripheral IV catheters if access site is not touched after the application of skin antiseptics. Wear sterile gloves for the insertion of arterial, central, and midline catheters. Wear new sterile gloves before handling the new catheter when guidewire exchanges are performed. Wear either clean or sterile gloves when changing the dressing on intravascular catheters.	IB IB IC IA II IC
Maximal sterile barrier precautions Use maximal sterile barrier precautions, including the use of a cap, mask, sterile gown, sterile gloves, and a sterile full body drape, for the insertion of CVCs, PICCs, or guidewire exchanges. Use a sterile sleeve to protect pulmonary artery catheters during insertion.	IB IB
Skin preparation Prepare clean skin with an antiseptic (70 percent alcohol, tincture of iodine, an iodophor or alcohol/chlorhexidine gluconate) before peripheral venous catheter insertion. Prepare clean skin with a >0.5 percent chlorhexidine preparation with alcohol before CVC and peripheral arterial catheter insertion and during dressing changes. If there is a contradiction to chlorhexidine, tincture of iodine, an iodophor, or 70 percent alcohol can be used as alternatives. No comparison has been made between using chlorhexidine preparations with alcohol and povidone-iodine in alcohol to prepare the skin. No recommendation can be made for the safety or efficacy of chlorhexidine in infants aged <2 months. Antiseptics should be allowed to dry according to the manufacturer's recommendation prior to placing the catheter.	IB IA Unresolved Unresolved IB

Catheter site dressing regimens Use either sterile gauze or sterile transparent, semipermeable dressing to cover the catheter site. If the patient is diaphoretic or if the site is bleeding or oozing, use a gauze dressing until this is resolved. Replace catheter site dressing if the dressing becomes damp, loosened, or visibly soiled. Do not use topical antibiotic ointment or creams on insertion sites, except for dialysis catheters, because of their potential to promote fungal infections and antimicrobial resistance. Do not submerge the catheter or catheter site in water. Showering should be permitted if precautions can be taken to reduce the likelihood of introducing organisms into the catheter (e.g., use of an impermeable cover). Replace dressings used on short-term CVC sites every 2 days for gauze dressings. Replace dressings used on short-term CVC sites at least every 7 days for transparent dressings, except in those pediatric patients in which the risk for dislodging the catheter may outweigh the benefit of changing the dressing. Replace transparent dressings used on tunneled or implanted CVC sites no more than once per week, unless the dressing is soiled or loose, until the insertion site has healed. No recommendation can be made regarding the necessity for any dressing on well-healed exit sites of long-term cuffed and tunneled CVCs. Ensure that catheter site care is compatible with the catheter material. Use a sterile sleeve for all pulmonary artery catheters. Use a chlorhexidine-impregnated sponge dressing for temporary short-term catheters in patients older than 2 months if the CLABSI rate is not decreasing despite adherence to basic prevention measures. No recommendation is made for other types of chlorhexidine dressings. Monitor the catheter sites visually when changing the dressing or by palpation through an intact dressing on a regular basis, depending on the clinical situation of the patient. If patients have tenderness at the insertion site, fever without obvious source, or other manifestations suggesting local or bloodstream infection, the dressing should be removed to allow thorough examination of the site. Encourage patients to report any changes in their catheter site or any new discomfort to their provider.	IA II IB IB IB II IB II Unresolved IB IB IB Unresolved IB II
Patient cleansing Use a 2 percent chlorhexidine wash for daily skin cleansing to reduce CRBSIs.	II
Catheter securement devices Use a sutureless securement device to reduce the risk of infection for intravascular catheters.	II
Antimicrobial/antiseptic impregnated catheters and cuffs Use a chlorhexidine/silver sulfadiazine or minocycline/rifampin-impregnated CVC in patients whose catheter is expected to remain in place >5 days if, after successful implementation of a comprehensive strategy to reduce rates of CLABSI, the CLABSI rate is not decreasing.	IA
Systemic antibiotic prophylaxis Do not administer systemic antimicrobial prophylaxis routinely before insertion or during use of an intravascular catheter to prevent catheter colonization or CRBSI.	IB

Antibiotic/antiseptic ointments Use povidone iodine antiseptic ointment or bacitracin/gramicidin/polymyxin B ointment at the hemodialysis catheter exit site after catheter insertion and at the end of each dialysis session only if the ointment does not interact with the material of the hemodialysis catheter per manufacturer's recommendation.	IB
Antibiotic lock prophylaxis, antimicrobial catheter flush and catheter lock prophylaxis Use prophylactic antimicrobial lock solution in patients with long-term catheters who have a history of multiple CRBSIs despite optimal maximal adherence to aseptic technique.	II
Anticoagulants Do not routinely use anticoagulant therapy to reduce the risk of catheter-related infection in general patient populations.	II
Replacement of peripheral and midline catheters There is no need to replace peripheral catheters more frequently than every 72 to 96 hours to reduce risk of infection and phlebitis in adults. No recommendation is made regarding replacement of peripheral catheters in adults only when clinically indicated. Replace peripheral catheters in children only when clinically indicated. Replace midline catheters only when there is a specific indication.	IB Unresolved IB II
Replacement of CVCs, including PICCs and hemodialysis catheters Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery catheters to prevent catheter-related infections. Do not remove CVCs or PICCs on the basis of fever alone. Use clinical judgment regarding appropriateness of removing the catheter if infection is evidenced elsewhere or if a noninfectious cause of fever is suspected. Do not use guidewire exchanges routinely for nontunneled catheters to prevent infection. Do not use guidewire exchanges to replace a nontunneled catheter suspected of infection. Use a guidewire exchange to replace a malfunctioning nontunneled catheter if no evidence of infection is present. Use new sterile gloves before handling the new catheter when guidewire exchanges are performed.	IB II IB IB IB II

Umbilical catheters Remove and do not replace umbilical artery catheters if any signs of CRBSI, vascular insufficiency in the lower extremities, or thrombosis are present. Remove and do not replace umbilical venous catheters if any signs of CRBSI or thrombosis are present. No recommendation can be made regarding attempts to salvage an umbilical catheter by administering antibiotic treatment through the catheter. Cleanse the umbilical insertion site with an antiseptic before catheter insertion. Avoid tincture of iodine but other iodine-containing products can be used. Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance. Add low-doses of heparin (0.25 to 1.0 U/mL) to the fluid infused through umbilical arterial catheters. Remove umbilical catheters as soon as possible when no longer needed or when any sign of vascular insufficiency to the lower extremities is observed. Optimally, umbilical artery catheters should not be left in place >5 days. Umbilical venous catheters should be removed as soon as possible when no longer needed, but can be used up to 14 days if managed aseptically. An umbilical catheter may be replaced if it is malfunctioning, and there is no other indication for catheter removal, and the total duration of catheterization has not exceeded 5 days for an umbilical artery catheter or 14 days for an umbilical vein catheter.	II II Unresolved IB IA IB II II II
Peripheral arterial catheters and pressure monitoring devices for adult and pediatric patients In adults, use of the radial, brachial, or dorsalis pedis sites is preferred over the femoral or axillary sites of insertion to reduce the risk of infection. In children, the brachial site should not be used. The radial, dorsalis pedis, and posterior tibial sites are preferred over the femoral or axillary sites of insertion. A minimum of a cap, mask, sterile gloves, and a small sterile fenestrated drape should be used during peripheral arterial catheter insertion. During axillary or femoral artery catheter insertion, maximal sterile Barriers Precautions should be used. Replace arterial catheters only when there is a clinical indication. Remove the arterial catheter as soon as it is no longer needed. Use disposable, rather than reusable, transducer assemblies when possible. Do not routinely replace arterial catheters to prevent catheter-related infections. Replace disposable or reusable transducers at 96-hour intervals. Replace other components of the system (including the tubing, continuous-flush device, and flush solution) at the time the transducer is replaced. Keep all components of the pressure monitoring system (including calibration devices and flush solution) sterile. Minimize the number of manipulations of and entries into the pressure monitoring system. Use a closed flush system (i.e., continuous flush), rather than an open system (i.e., one that requires a syringe and stopcock), to maintain the patency of the pressure monitoring catheters. When the pressure monitoring system is accessed through a diaphragm, rather than a stopcock, scrub the diaphragm with an appropriate antiseptic before accessing the system. Do not administer dextrose-containing solutions or parenteral nutrition fluids through the pressure monitoring circuit. Sterilize reusable transducers according to the manufacturers' instructions if the use of disposable transducers is not feasible.	IB II IB II II II IB II IB IA II IA IA IA

Replacement of administration sets In patients not receiving blood, blood products, or fat emulsions, replace administration sets that are continuously used, including secondary sets and add-on devices, no more frequently than at 96-hour intervals, but at least every 7 days. No recommendation can be made regarding the frequency for replacing intermittently used administration sets. No recommendation can be made regarding the frequency for replacing needles to access implantable ports. Replace tubing used to administer blood, blood products, or fat emulsions within 24 hours of initiating the infusion. Replace tubing used to administer propofol infusions every 6 or 12 hours, when the vial is changed, per the manufacturer's recommendation. No recommendation can be made regarding the length of time a needle used to access implanted ports can remain in place.	IA Unresolved Unresolved IB IA Unresolved
Needleless intravascular catheter systems Change the needleless components at least as frequently as the administration set. There is no benefit to changing these more frequently than every 72 hours. Change needleless connectors no more frequently than every 72 hours or according to manufacturers' recommendations for the purpose of reducing infection rates. Ensure that all components of the system are compatible to minimize leaks and breaks in the system. Minimize contamination risk by scrubbing the access port with an appropriate antiseptic and accessing the port only with sterile devices. Use a needleless system to access IV tubing. When needleless systems are used, a split septum valve may be preferred over some mechanical valves due to increased risk of infection with the mechanical valves.	II II II IA IC II
Performance improvement Use hospital-specific or collaborative-based performance improvement initiatives in which multifaceted strategies are "bundled" together to improve compliance with evidence-based recommended practices.	IB

*Taken from CDC/HICPAC system of weighting recommendations based on scientific evidence. IA, Strongly recommended for implementation and strongly supported by well-designed experimental, clinical or epidemiological studies. IB, Strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and a strong theoretical rationale; or an accepted practice (e.g., aseptic technique) supported by limited evidence. IC, Required by state or federal regulations, rules or standards. II, Suggested for implementation and supported by suggestive clinical or epidemiological studies or a theoretical rationale. Unresolved issue, Represents an unresolved issue for which evidence is insufficient or no consensus regarding efficacy exists.

BSI, bloodstream infection; CRBSI, catheter-related bloodstream infection; CVC, central venous catheter; ICU, intensive care unit; IV, intravenous; IVD, intravascular device; PICC, peripherally inserted central catheter.

Adapted from O'Grady NP, Alexander M, Burns LA, et al. Guidelines for the prevention of intravascular catheter-related infections. *Am J Infect Control*2011;39:S1–34.

Barrier Precautions

Hand hygiene with an antiseptic-containing preparation, either conventional hand washing with an antiseptic-containing soap or with a waterless alcohol rub or gel,[127]must always precede the insertion of

an IVD and should also precede subsequent handling of the device or its administration set.[128] A new pair of disposable nonsterile gloves, donned using a "no-touch" technique, is adequate for the placement of peripheral IV catheters in most patients; however, sterile gloves should be used during insertion in high-risk patients, such as those with granulocytopenia. Sterile gloves are strongly recommended for placement of all other types of IVDs that are associated with a 1 percent or higher risk of associated bacteremia, specifically arterial catheters and all types of CVCs, including PICCs.[109]

Studies have shown that the use of *maximal barriers*—including a long-sleeve, sterile surgical gown, mask, cap, and large sterile drape (head to toe), as well as sterile gloves—significantly reduces the risk of CVC-associated BSI (0.08 BSIs with maximal barriers versus 0.5 BSIs per 1,000 IVD days without maximal barriers; $p \equiv .02$).[129] The use of maximal barriers has further been shown to be highly cost effective.[129] Considering that of all IVDs, CVCs are most likely to produce healthcare-associated BSI, a strong case can be made for *mandating* maximal Barrier Precautions during the insertion of all central IVDs.[109] However, they are not necessary for arterial catheters used for hemodynamic monitoring, where a cap, mask, sterile gloves, and a small sterile fenestrated drape will suffice.[109,130]

Intravenous Teams

Good technique is also essential. Studies have shown that the use of special IV therapy teams, consisting of trained nurses or technicians who can assure a consistent and high level of aseptic technique during catheter insertion and in follow-up care of the catheter, have been associated with substantially lower rates of catheter-associated BSI and are cost effective.[131,132] But even if an institution does not have an IV team, it can greatly reduce its rate of IVDA BSI by *formal education of nurses and physicians* and stringent adherence to IVD care protocols.[133,134]

Cutaneous Antisepsis

Given the evidence for the importance of cutaneous microorganisms in the pathogenesis of short-term IVDA infections, measures to reduce colonization of the insertion site would seem of the highest priority, particularly the choice of chemical antiseptics for disinfection of the site. In the United States, iodophors such as 10 percent povidone-iodine historically were used most widely.[135] However, a number of studies have subsequently demonstrated the superiority of chlorhexidine-containing antiseptics for preparation of the skin prior to insertion of a short-term IVD when compared to either povidone-iodine or alcohol.[33,136,137,138,139,140,141,142,143] In the largest study to date, a randomized trial in 1,050 CVCs and arterial catheters placed in a university hospital ICU, cutaneous antisepsis with 1 percent tincture of chlorhexidine showed a highly significant reduction in IVDA BSIs compared with antisepsis with an iodophor (RR ≡ 0.35; $p < .01$).[143] More recently, a meta-analysis that examined results from eight of the nine aforementioned studies found that use of chlorhexidine was associated with a nearly 50 percent reduction in the risk of IVDA compared with povidone-iodine (RR ≡ 0.49; 95 percent CI ≡ 0.28 to 0.88).[144] On the basis of these results, chlorhexidine-containing antiseptics are now considered a standard of care for skin preparation prior to insertion of CVCs in adults.[109,110,145] Contact dermatitis associated with the use of a chlorhexidine-containing sponge dressing has been reported to be significantly more common in children younger than 28 weeks' gestational age and in those with birth weights of less than 1,000 g.[146] As a result, recent guidelines have discouraged the use of chlorhexidine for CVC insertion

site preparation in children younger than 2 months of age.[110] In these situations, povidone-iodine should be used.

INSERTION SITE CARE AND INTRAVASCULAR DEVICE MAINTENANCE

Intravascular Device Dressings

IVDs can be dressed with sterile gauze and tape or with a sterile transparent, semipermeable, polyurethane film dressing. The available data suggest that the two types of dressings are equivalent in terms of their impact on IVDA BSI with peripheral IVs and short-term CVCs.[39,147,148,149,150,151,152] In contrast, results from studies of arterial catheters have found that polyurethane dressings greatly increase the risk of IVDA BSI.[149,153] As a result, polyurethane dressings should probably not be used on arterial catheters until future studies confirm their safety.

Topical Antimicrobial Ointments

In theory, application of a topical antimicrobial agent to the catheter insertion site should confer some protection against microbial invasion. Clinical trials of a topical combination antibacterial ointment containing polymyxin, neomycin, and bacitracin with peripheral IVs have shown marginal benefit,[154,155,156] but the use of polyantibiotic ointments has been associated with a fivefold increased frequency of *Candida* infection, limiting their utility.[156,157]

The topical antibacterial mupirocin, which is active primarily against Gram-positive organisms, was shown in one study to significantly reduce colonization of internal jugular catheters without increasing colonization by *Candida* spp.,[158] and a more recent study by Sesso et al. showed significant reductions in hemodialysis catheter colonization (3.17 versus 14.27 per 1,000 IVD days; $p < .001$) and *S. aureus* IVDA BSIs (0.71 versus 8.92 BSIs per 1,000 IVD days; $p < .001$).[159] Unfortunately, resistance of *S. aureus*[160] and coagulase-negative staphylococci[161] rapidly emerges during widespread mupirocin use,[162] which contravenes its general use as a topical agent for the prevention of IVDA BSI at this time.[109]

Three prospective studies of topical povidone-iodine ointment applied to CVC sites have failed to show a statistical benefit to its use,[156,163,164] but a single comparative trial in subclavian hemodialysis catheters showed that the use of topical povidone-iodine ointment was associated with a fourfold reduction in the incidence of IVDA *S. aureus* BSI.[165] Povidone iodine antiseptic ointment or bacitracin/gramicidin/polymyxin B ointment (not currently available in the United States) is currently recommended for use at the hemodialysis catheter exit site after catheter insertion and at the end of each dialysis session only if the ointment does not interact with the material of the hemodialysis catheter per manufacturer's recommendation.[109]

Replacement of the Device

Studies have shown that peripheral IVs may safely be left in place for as long as 96 hours if the patient and the insertion site are monitored closely.[32,166,167] Recent studies have suggested that the duration of peripheral catheterization may be prolonged even further;[168] however, there have been recent reports of

increasing healthcare-associated *S. aureus*bacteremias linked to prolonged peripheral venous catheterization,[169]so more studies are required before this can become a standard recommendation.

Scheduled replacement of short-term, noncuffed, and nontunneled CVCs has long been practiced in many centers; however, studies have called this practice into question.[170,171,172]Moreover, a meta-analysis found no benefit to routine replacement of short-term CVCs.[173]Based on these data, there appears to be no indication for scheduled replacement of short-term CVCs that are functioning well and show no clinical signs of infection.

Guidewire Exchanges of Central Venous Catheters

The management of CVCs that must be replaced, either because of mechanical malfunction or suspected infection, deserves special attention. Replacement of CVCs by guidewire exchange is associated with a reduced risk of mechanical complications;[172,173]however, it is also associated with an increased risk of the newly placed CVC becoming infected and causing CVC-associated BSI.[172]As result, if circumstances necessitate guidewire exchange for placement of a new catheter (e.g., the patient has limited new access sites, is morbidly obese, or is at high risk of mechanical complications because of underlying coagulopathy), the same strict aseptic technique, which includes full Barrier Precautions, must be used. However, the tip or intracutaneous segment(s) of the removed CVC also should routinely be sent for culture to determine whether the insertion tract is colonized because, if it is, the newly exchanged CVC should be promptly removed and a new CVC placed percutaneously in a new site; if the tract is not colonized, the newly exchanged CVC can remain in the old insertion site.

Although small studies have found some utility of guidewire exchange in the management of CVCs suspected of being infected,[174,175,176,177]in the absence of randomized studies demonstrating its safety, guidewire exchange generally should not be performed if there is suspicion of IVDA BSI, especially if there are signs of local infection, such as purulence or erythema at the insertion site, or signs of systemic sepsis without a source. In these cases, the old catheter should be removed and cultured, and a new catheter should be inserted in a new site.

Replacing the Delivery System

Whereas most infusion-associated BSIs are caused by infection of the device used for vascular access, infusate can become contaminated and cause occasional endemic BSIs.[28,178]If an infusion runs continuously for an extended period, the cumulative risk of contamination increases, and there is further risk that contaminants can grow to concentrations that could produce BSI in the recipient of the fluid. For more than 25 years, most U.S. hospitals have routinely replaced the entire delivery system of patients' IV infusions at 24- or 48-hour intervals[179]to reduce the risk of BSI from extrinsically contaminated fluid. Prospective studies indicate that IV delivery systems need not be replaced more frequently than at 96 hours but at least every 7 days, unless the patient is receiving blood, blood products, or fat emulsions;[109,167,180]extending the duration of use permits considerable cost savings to hospitals.[180]

Exceptions to using 96 hours as an interval for routine set change include:[109,180](1) administration of blood products; (2) administration of lipid emulsion; or (3) a suspected epidemic of infusion-associated

BSI. In these circumstances, it may be most prudent that administration sets be changed within 24 hours of initiating the infusion.[109]

Arterial infusions used for hemodynamic monitoring appear to be more vulnerable to becoming contaminated during use and producing endemic[178] or epidemic septicemia[181] caused by Gram-negative bacilli. If the infusion for hemodynamic monitoring is set up so that the fluid flows continuously through the chamber dome, thus eliminating a blind stagnant column of fluid, extrinsic contamination appears to be greatly reduced, and may even eliminate the need to replace the administration set, chamber dome, and other components of the system at frequent intervals.[182,183,184,185] If disposable transducers and chamber domes are used, there appears to be no need to replace the transducer assembly and other components of the delivery system more frequently than every 4 days,[182] and it may be safe to replace even less frequently.[183,184,185]

Anticoagulants and Thrombolytics

Thrombus formation on an IVD is associated with an increased risk of infection.[186,187,188,189] Two prospective studies have been performed to examine the efficacy of warfarin anticoagulation for reducing rates of IVDA thrombosis with long-term IVDs.[190,191] Both studies found that use of warfarin in a dose of 1 mg/day was associated with significantly reduced rates of thrombosis with long-term IVDs, although no data were provided on rates of IVDA BSI.

The use of prophylactic heparin for reducing rates of IVDA thrombosis and infection has been evaluated in a meta-analysis.[192] Evaluating a variety of different administration techniques from 14 randomized controlled studies, Randolph et al. showed that heparin significantly reduced the risk of IVDA thrombosis (RR ≡ 0.43; 95 percent CI 0.23 to 0.78) and device colonization (RR ≡ 0.18; 95 percent CI ≡ 0.06 to 0.6) but failed to show a reduction in IVDA BSIs.[192] Heparin-bonded pulmonary artery catheters may be less prone to IVDA BSI than are nonheparinized catheters.[28,193,194,195]

Based on the cited studies, low-level anticoagulation with warfarin is warranted for long-term IVDs as long as there is no contraindication (bleeding diathesis, brain tumor, or predilection to falls) and the international normalized ratio is maintained below 1.6.[190] For short-term IVDs, the use of low-dose subcutaneous heparin is more appropriate because it is commonly given to patients with CVCs or arterial lines, as part of hospital thromboembolism prophylaxis.[196]

The prophylactic installation of urokinase (5,000 IU/mL) into long-term IVDs every 1 to 2 weeks has been shown to significantly reduce the incidence of thrombotic complications.[197] Less clear is the effect of prophylactic use of thrombolytics on the risk of IVDA. One study found a reduced risk of infection with weekly urokinase;[197] however, a more recent study failed to identify any benefit.[198]

USE OF NOVEL TECHNOLOGY

Despite compliance with recommended guidelines, many centers continue to have high rates of IVDA BSI. Here, novel technology holds much promise (Table 34-8). Innovative technologies designed to reduce the risk of IVDA BSI have proven not only to be effective but also to reduce healthcare costs, with short-term and long-term IVDs.[24,199]

NOVEL SECUREMENT DEVICES

Recently, a novel sutureless device for securing noncuffed vascular catheters has become available (StatLock, Venetec International, San Diego, CA). In a randomized trial of the device, premature loss of pediatric PICCs due to accidental extrusion and PICC-associated thrombosis were significantly reduced,[200] and in two additional trials the incidence of catheter-associated BSI was significantly reduced with the use of the novel securement device, both in adults and children with PICCs.[201,202]

The promise of this device for reducing infection may derive from elimination of a festering skin suture wound contiguous to the newly inserted catheter and minimizing to-and-fro movement of the catheter, which may promote invasion of the tract by cutaneous microorganisms through capillary action.[203]

Table 34-8 Novel Technology That has Been Examined in Randomized Clinical Trials

Chlorhexidine for cutaneous antisepsis

Securement device

Topical anti-infective creams or ointments

Polymyxin, neomycin, bacitracin polyantibiotic ointment

Povidone-iodine ointment

Mupirocin ointment

Dressings

Transparent, polyurethane film dressings

Hyperpermeable polyurethane dressings

Hydrocolloid dressings

Chlorhexidine-impregnated sponge dressings

Innovative IVD design

Cuffed and tunneled CVCs

Subcutaneous central venous ports

Attachable silver-impregnated cuffs

Peripherally inserted central venous catheters

Anti-infective-coated catheters

Benzalkonium chloride-impregnated catheters

Chlorhexidine-silver sulfadiazine-coated catheters

Cefazolin-coated catheters

Minocycline-rifampin-coated catheters

Silver-impregnated catheters

Anti-infective catheter hubs

Iodinated chamber

External povidone-iodine-saturated sponge cap

Anti-infective lock solutions for long-term IVDs

Vancomycin

Vancomycin/ciprofloxacin

Trisodium citrate/gentamicin

Minocycline/ethylenediaminetetraacetic acid (EDTA)

Ethanol

Taurolidine

Scheduled (prophylactic) thrombolysis with urokinase

CVC, central venous catheter; IVD, intravascular device.

Adapted from Crnich CJ, Maki DG. The promise of novel technology for the prevention of intravascular device-related bloodstream infection. I. Pathogenesis and short-term devices. *Clin Infect Dis*2002;34(9):1232–1242; Crnich CJ, Maki DG. The promise of novel technology for the prevention of intravascular device-related bloodstream infection. II. Long-term devices. *Clin Infect Dis*2002;34(10):1362–1368.

Novel Dressings

Studies of polyurethane dressings, which contain antiseptic, such as povidone-iodine or ionized silver, have been disappointing. However, based on the demonstrated superiority of chlorhexidine for cutaneous disinfection of access sites, a novel chlorhexidine-impregnated sponge dressing has been developed (Biopatch, Johnson and Johnson Medical Inc., Kalamazoo, MI) that maintains a very high concentration of the antiseptic on the insertion site under the dressing. The first study to examine the effectiveness of the chlorhexidine-impregnated sponge dressing found that it was associated with a 60 percent reduction in catheter-associated BSI (RR ≡ 0.37; *p*≡ .01).[203] A recently published multicenter trial found that rates of catheter-associated BSIs in subjects randomized to the chlorhexidine-impregnated sponge dressing were significantly lower (0.6 BSIs per 1,000 catheter days) compared with subjects randomized to a standard dressing (1.4 BSIs per 1,000 catheter days; hazard ratio [HR] ≡ 0.39; 95 percent CI ≡ 0.17 to 0.93).[204] Although neither study identified adverse side effects associated with the use of this dressing in adult populations, a separate pediatric trial found that ~15 percent of low-birth-weight neonates experienced local dermatotoxicity.[146]

Anti-infective Impregnated Catheters

Intravascular devices directly coated or impregnated with antimicrobials or antiseptics have been intensively studied during the past decade. Eighteen randomized trials evaluating the efficacy of chlorhexidine-silver sulfadiazine- or minocycline-rifampin-impregnated CVCs have been published in full article or abstract form since 1994.[40,41,84,90,117,205,206,207,208,209,210,211,212,213,214,215,216,217]

Twelve of the 16 published studies that examined the effect of antimicrobial-impregnated CVCs on rates of CVC-associated BSI found either a statistically significant reduction[41,42,90] or a strong trend toward a reduction in rates of CVC-associated BSI.[205,207,208,211,212,213,214,215,217] Aggregate analysis of the 15 studies that compared antimicrobial-impregnated CVCs to nonimpregnated CVCs, encompassing a total of 4,250 CVCs, shows that antimicrobial-impregnated CVCs are associated with a 40 percent reduction in CVC-associated BSI (61 BSIs in 2,129 devices versus 101 BSIs in 2,118 devices; odds ratio [OR] ≡ 0.60; 95 percent CI ≡ 0.44 to 0.82; *p*≡ .001),[218] a result remarkably similar to the findings of three published meta-analyses.[24,219,220]

Finally, two rigorous and sophisticated economic analyses have found that antimicrobial-impregnated CVCs are cost effective.[221,222] Veenstra et al. showed that antimicrobial-impregnated CVCs remained cost effective even if the cost of a CVC-associated BSI was as low as $687 per case; cost savings were $196 dollars per antimicrobial-impregnated CVC when a more realistic cost of a CVC-associated BSI of $9,738 was used in the analysis.[221] Shorr et al. showed that use of antimicrobial-impregnated CVCs was associated with a cost savings of $9,600 per CVC-associated BSI prevented and that $165 to $280 would be saved for every patient who received an antimicrobial-impregnated CVC.[222]

On the basis of this large body of data, three national advisory panels have recommended the use of antimicrobial-impregnated CVCs in clinical settings where, despite rigorous application of other preventative interventions, rates of IVDA remain unacceptably high (i.e., ≥3.3 BSIs per 1,000 IVD days).[109,110,223]

Antimicrobial Lock Solutions

Given the importance of hub contamination and intraluminal colonization in the genesis of IVDA BSI with long-term IVDs, intraluminal installation of an antibiotic or antiseptic solution has the potential to reduce the risk of BSI associated with these devices. A total of 12 randomized trials have examined the effect of an antibiotic lock solution (ALS) for the prevention of IVDA BSI, 4 in subjects with long-term nonhemodialysis CVCs[224] and 8 in subjects with hemodialysis CVCs.[225] Two separate meta-analyses found that prophylactic use of an ALS reduced the risk of IVDA BSI in subjects with nonhemodialysis CVCs by 66 percent (RR ≡ 0.34; 95 percent CI ≡ 0.12 to 0.98)[224] and reduced the risk of IVDA BSI in subjects with a hemodialysis CVC by 68 percent (RR ≡ 0.32; 95 percent CI ≡ 0.10 to 0.42).[225] Concern about the emergence of resistance with prophylactic antibiotic-containing lock solutions has limited their acceptance to date. However, the use of prophylactic antibiotic lock solution is considered acceptable in the HICPAC guideline if a patient with an essential long-term IVD has continued to experience recurrent IVDA BSIs despite consistent application of infection prevention practices.[109,110]

At the current time, lock solutions containing vancomycin have been the most well studied.[224] Lock solutions containing other antimicrobial agents, such as gentamicin, cephalosporins, and minocycline, also have been shown to be beneficial in certain patient populations,[225] whereas lock solutions containing nonantimicrobial antiseptics, such as trisodium citrate,[226] ethanol,[227] and taurolidine,[228,229] are increasingly being reported. However, concerns about increased IVD complication rates[230] and drug-related toxicity[226] associated with agents from this latter group of lock solutions, combined with the limited number of patients who have been studied while receiving these agents, precludes their routine use at this time.

Catheter Hubs

In most U.S. medical centers, needleless access devices have largely supplanted hub designs that require healthcare personnel (HCP) to manipulate a needle. Needleless devices clearly reduce the risk of HCP percutaneous injuries.[230] However, newer hub designs that involve Luer-activated or mechanical valve systems have been implicated in several outbreaks of IVDA BSI.[231,232,233] The increased complexity of the inner surfaces and the propensity of the septum of some of these devices to develop surface irregularities can promote bacterial adherence and render them intrinsically more susceptible to contamination, even when proper antisepsis procedures are followed.[234] As a result, it is important that purchasing decisions regarding needleless devices involve members of the infection prevention department.

A novel catheter hub that contains a chamber filled with iodinated alcohol has been shown to be effective in preventing colonization of IVDs in an animal model.[235] Use of this same hub model in some clinical studies has demonstrated significantly lower rates of IVD colonization compared with IVDs with control hubs.[236,237] One clinical trial has also demonstrated reduced rates of IVDA BSIs (4 percent versus 16 percent; $p < .01$)[236] with the use of this hub. A subsequent study also showed a reduction in hub-

associated IVDA BSIs (1.7 percent versus 7 percent; $p < .049$); however, overall rates of IVDA BSIs in both groups were similar,[237] and another study was unable to find any benefit with regard to IVD colonization or IVDA BSI with use of the novel hub.[238] This device is not yet available in the United States, and until additional studies conclusively demonstrate its benefit, its use cannot be recommended.

PRACTICAL APPROACHES TO PREVENTING INTRAVASCULAR DEVICE BLOODSTREAM INFECTION

Recent studies have shown that consistent application of high-yield preventative interventions can lead to substantial and sustained reductions in facility rates of IVDA BSI.[133,145,239,240,241,242] For example, Pronovost et al. implemented a multifactorial intervention focused on consistently applying a "bundle" of select evidence-based recommendations for the prevention of IVDA BSI in 103 ICUs in Michigan.[145]

Application of the following five simple interventions led to a nearly 40 percent reduction in the incidence rate of IVDA BSI that was sustained over 18 months of follow-up: (1) hand hygiene before CVC insertion; (2) avoiding insertion of CVCs in femoral sites; (3) preparation of the skin insertion site using chlorhexidine; (4) using maximal sterile barriers when inserting CVCs; and (5) removing the CVC as soon as possible.[145,243] Successful implementation of these interventions was facilitated through engagement of unit leadership and clinical champions, education of clinical staff, standardization of insertion practices through the use of catheter insertion kits and CVC insertion checklists, and development of a multidisciplinary rounding system to help facilitate monitoring of CVC insertion and maintenance practices.

If rates of IVDA BSI remain unacceptably high after implementation of basic infection prevention measures, hospitals should consider introduction of novel technology to reduce rates further. Decisions on which technology to implement should be based on the types of CVCs being used, the patient populations most affected by IVDA BSI, alterations in workflow, and the additional equipment costs that may occur when introducing the new technology.

Treatment Of Intravascular Device Bloodstream Infection

MANAGEMENT OF THE DEVICE

Short-term Intravascular Devices

If a short-term vascular catheter is suspected of being infected because the patient has no obvious other source of infection to explain fever, there is inflammation at the insertion site, or cryptogenic staphylococcal bacteremia or candidemia has been documented, blood cultures should be obtained and *the catheter should be removed and cultured*(Table 34-9). Failure to remove an infected catheter puts the patient at risk of developing septic thrombophlebitis with peripheral IV catheters, septic thrombosis of a great central vein with CVCs,[244,245] or even endocarditis. Continued access, if necessary, can be established with a new catheter inserted in a new site. A new catheter should never be placed in an old site over a guidewire if the first catheter is suspected of being infected, especially if there is purulence at the site.

Table 34-9 Algorithm for Diagnosis and Management of Intravascular Device-associated Bloodstream Infection

• Examine the patient thoroughly to identify unrelated sources of infection.

• Carefully examine all catheter insertion sites; Gram stain and culture any expressible purulence.

• Obtain *two*10- to 15-mL cultures:

If standard (nonquantitative) blood cultures, draw one by *percutaneous peripheral*venipuncture and one through the suspect IVD.

If quantitative blood culture techniques are available (e.g., the Isolator system), catheter-drawn cultures can enhance the diagnostic specificity of blood culturing in the diagnosis of line sepsis. However, a peripheral percutaneous quantitative blood culture *must*be drawn *concomitantly*.

• Option regarding a peripheral IV or arterial catheter: *remove and culture catheter*.

• Options regarding a short-term central venous catheter:

*Purulence*at insertion site or no purulence, but patient *floridly septic, without obvious source*:

Remove and culture catheter.

Gram stain purulence.

Reestablish access at new site.

No purulence, patient not floridly septic:

Leave catheter in place, pending results of blood cultures.

or

Remove and culture catheter, reestablish needed access at new site.

• Options regarding surgically implanted, cuffed Hickman-type catheters.

Remove at outset if:

*Infecting*organism known to be *Staphylococcus aureus*, *Bacillus*spp., JK diphtheroid, *Mycobacterium*species, or filamentous fungus.

Refractory or progressive exit-site infection, despite antimicrobial therapy, especially with *Pseudomonas aeruginosa*.

Tunnel infected.

Evidence of septic thrombosis of cannulated central vein or septic pulmonary emboli.

Evidence of endocarditis.

Remove later on if:

Any of the above become manifest.

BSI persists ≥3 days, despite IV antimicrobial therapy through catheter.

• Options regarding surgically implanted subcutaneous central ports (e.g., Portacath):

Cellulitis without documented bacteremia: begin antimicrobial therapy, *withhold removing port*.

Aspirate from port shows organisms on Gram stain or heavy growth in quantitative culture, or documented port bacteremia: *remove port*.

• Decision on whether to begin antimicrobial therapy, before culture results available, based on clinical assessment and/or Gram stain of exit site or the blood drawn from a long-term IVD.

• With no microbiologic data to guide antimicrobial selection in a septic patient with suspected line sepsis, consider: *IV vancomycin and ciprofloxacin, cefepime, or imipenem/meropenem*.

BSI, bloodstream infection; IVD, intravascular device.

Maki DG. Management of life-threatening infection in the intensive care unit. In: Murray MJ, Coursin DB, Pearl RG, et al, eds. *Critical Care Medicine: Preoperative Management*, 2nd ed. Philadelphia: Lippincott Williams & Williams, 2002:616–648.

Long-term Intravascular Devices

BSI that might have originated from a cuffed and tunneled CVC does not automatically mandate removal of the device unless there has been persistent exit site infection; the tunnel is obviously infected; there is evidence of complicating endocarditis, septic thrombosis, or septic pulmonary emboli; the infecting pathogen is *S. aureus, Corynebacterium* JK, a *Bacillus* species, *Stenotrophomonas* spp., *Burkholderia cepacia*, any pseudomonal species, a filamentous fungus, *Malassezia*species, or a mycobacterial species; or bacteremia or candidemia persists for more than 3 days despite adequate therapy (Table 34-9).[246]

IVDA BSI caused by *S. aureus*must always prompt removal of the IVD, even if signs of bacteremia have resolved following antimicrobial therapy, because of the significant risk of infectious endocarditis (IE) or other metastatic infection if bacteremia recurs.[247,248,249]Authors of several small nonrandomized studies in patients with cuffed and tunneled hemodialysis catheters that subsequently became infected with various organisms, including *S. aureus*, have been able to successfully replace infected catheters by guidewire exchange and achieve cure rates in the range of 75 to 82 percent when combined with systemic antibiotics.[175,250,251]Although this approach may allow preservation of an access site and minimize mechanical complications, randomized studies are needed to show whether guidewire exchange of infected catheters has a long-term success rate comparable with removal of the infected IVD and placement of a new catheter at another site.

Likewise, patients with IVDA candidemia should have their catheter removed in most situations.[252] Several studies have reported successful treatment of IVD BSIs due to *Candida* spp. without IVD removal with prolonged courses of amphotericin B administered through the catheter;[253]however, this is in contrast to the results of other prospective studies that have found an increased duration of candidemia and mortality in patients who retain their infected IVD.[254]

Studies using 7 to 21 days of antibiotics infused through the infected line, primarily with BSIs caused by coagulase-negative staphylococci, have shown success rates of 60 to 91 percent without catheter removal,[246]although there was considerable variability in the clinical response, depending on the infecting microorganism; with coagulase-negative staphylococcal BSIs, the risk of recurrent bacteremia has been approximately 20 percent.[255]

In small, uncontrolled clinical trials of "antibiotic lock therapy" (ALT), usually in conjunction with systemic antibiotic therapy, cure rates of infected IVDs in excess of 90 percent have been reported.[256,257,258,259,260,261,262,263,264,265,266,267,268]Most IVDs reported in these studies were infected with coagulase-negative staphylococci and fermenting Gram-negative bacilli, so at this time ALT cannot be recommended for the management of long-term IVDs infected by *S. aureus, Bacillus* spp., *Corynebacterium* JK, *Stenotrophomonas* spp., *B. cepacia*, any pseudomonas species, fungi, or mycobacterial species. Table 34-10 lists the types of lock solutions that have been studied most extensively, although this table lacks data limits recommending one solution over another. Obviously, if IVDA BSI recurs after an attempt to salvage the IVD with ALT, the device should be removed.

Historically, infected surgically implanted subcutaneous central ports have rarely proven to be curable with medical therapy alone, especially if the device itself is clearly infected (e.g., an aspirate from the port shows heavy growth).[269,270,271]In vitro studies of several antibiotic lock solutions in simulated

models of subcutaneous central ports raise the possibility of using ALT to preserve the use of these long-term devices when they become infected.[272,273] A recent study of patients with acquired immunodeficiency syndrome (AIDS) with surgically implanted ports who developed IVDA BSI found that ALT combined with systemic antibiotic therapy resulted in 70 percent of the ports being salvaged; however, long-term follow-up data on surveillance cultures of the ports were not reported.[274] The only other clinical study of the utilization of ALT in subcutaneous central port infections achieved salvage rates of less than 50 percent.[275] Based on the marginal efficacy of ALT in these two studies and the historically poor cure rate achieved with systemic antibiotics alone, definitive treatment of infected subcutaneous central ports requires removal of the infected device.

Table 34-10 Formulations of Various Antibiotic-containing Lock Solutions Reported in the Medical Literature

Drug	Dosage	Dwell Time	Duration of Therapy	Stability with Heparin Solutions
Vancomycin	1 to 5 mg/mL	8 to 24 hours	7 to 15 days	Heparin 10 to 100 units/mL has been shown to be safe when coadministered with low-dose vancomycin (1 to 5 mg/mL) High-dose vancomycin (83 mg/mL) has been used successfully without coadministration of heparin.[264]
Teicoplanin	133 mg/mL	24 hours	5 to 9 days	Heparin 10 units/mL
Gentamicin	1 to 13.3 mg/mL	8 to 72 hours	5 to 21 days	Gentamicin precipitates rapidly in heparin solutions when gentamicin doses ≥5 mg/mL are used. A single study has reported the stability of 1 mg/mL of gentamicin in solutions with heparin concentrations as high as 2,500 units/mL.[271]
Amikacin	1.5 to 2 mg/mL	12 to 24 hours	6 to 27 days	Most studies have not addressed the issue of stability of amikacin with heparin. A single study utilizing amikacin concentrations as high as 40 mg/mL reported no drug precipitation in heparin (100 units/mL), although formal stability studies were not performed.[259]

Adapted, in part, from Berrington A, Gould FK. Use of antibiotic locks to treat colonized central venous catheters. J Antimicrob Chemother 2001;48(5):597–603.

ANTI-INFECTIVE THERAPY

In general, the selection of an initial antimicrobial regimen for a septic patient is influenced by (1) whether the presumed infection was acquired in the community or was institutionally acquired, (2) the age of the patient, and (3) whether or not the patient is immunocompromised, especially granulocytopenic (<1,000 per mm^3).[246]

If IVDA BSI is suspected (see Table 34-6) after cultures have been obtained, the combination of IV vancomycin (for staphylococci resistant to methicillin) with a fluoroquinolone—preferably ciprofloxacin, cefepime, or imipenem/meropenem (for multiresistant healthcare-associated Gram-negative bacilli)—should prove effective against the bacterial pathogens most likely to be encountered (see Figure 34-2). Initial therapy can then be modified based on the ultimate microbiologic identification and susceptibilities of the infecting organisms.

How long to treat IVDA BSI will be influenced by the infecting microorganism and by whether the patient has underlying valvular heart disease, evidence of endocarditis or septic thrombosis, or shows evidence of metastatic infection. If endocarditis is suspected, transesophageal echocardiography, as compared with transthoracic echocardiography, offers superior sensitivity and discrimination for detecting vegetations.[249] In patients with high-grade bacteremia or fungemia but without clinical or echocardiographic evidence of endocarditis, septic thrombosis should be suspected.[245] Central venous thrombosis can now be diagnosed by venography,[250] ultrasonography,[276] magnetic resonance imaging,[277] or computed tomography.[278]

Although there are no prospective data to guide the optimal duration of antimicrobial therapy for IVDA BSIs, most coagulase-negative staphylococcal infections can be cured with only 5 to 7 days of therapy,[43,255] whereas most infections caused by other microorganisms can be adequately treated with 10 to 14 days of antimicrobial therapy.[43] These recommendations hold only as long as there are no complications related to the infection and the BSI clears within 72 hours of initiating therapy. Healthcare-associated enterococcal bacteremia deriving from an IVD is rarely associated with persistent endovascular infection, and unless there is clinical or echocardiographic evidence of endocarditis, treatment with IV ampicillin or vancomycin alone for 7 to 14 days should suffice.[279]

The management of *S. aureus* device-associated infection deserves special mention because there have been no prospective studies to evaluate the optimal duration of therapy for IVDA BSIs caused by this ubiquitous human pathogen. Historically, high rates of associated IE and late complications led to a universal policy of 4 to 6 weeks of antimicrobial therapy for all patients with *S. aureus* bacteremia. Earlier diagnosis and initiation of bactericidal therapy of healthcare-associated *S. aureus* BSIs in recent years have been associated with lower rates of IE and metastatic complications, prompting suggestions that short-course therapy (i.e., 14 days) is effective and safe for most patients with *S. aureus* IVDA BSI, as long as the patient defervesces within 72 hours and there is no evidence of metastatic infection.[280] In a study of transesophageal echocardiography (TEE) in 103 hospitalized patients with *S. aureus* bacteremia, 69 related to an IVD, Fowler et al. found a surprisingly high incidence of endocarditis, 23 percent with IVDA *S. aureus* BSI.[249] In a more recent report, these authors have reported that the routine use of TEE with IVDA *S. aureus*BSI as a means to stratify patients into short-course or long-course therapy is cost effective.[281] However, at this time there are no prospective studies to affirm this approach. Until more data are available, short-course therapy for IVDA *S. aureus* bacteremia should be approached with caution and used only when the TEE is unequivocally negative and the patient has defervesced within 72 hours of removing the IVD and starting anti-infective therapy.

All patients with IVDA candidemia should be treated, even if the patient becomes afebrile and blood cultures spontaneously revert to negative following removal of the catheter without antifungal therapy.[252,]

[282,283]IVDA candidemia that responds rapidly to removal of the catheter and institution of IV amphotericin B can be reliably treated with a daily dose of 0.3 to 0.5 mg/kg and a total dose of 3 to 5 mg/kg.[282] If a lipid-associated formulation of amphotericin B is being used, a daily dose of 1 to 2 mg/kg and total dose of 10 to 20 mg/kg should be sufficient in most cases.[284] If the patient has septic thrombosis of central vein associated with high-grade candidemia and florid sepsis, a higher dose of IV amphotericin B is recommended: 0.7 mg/kg/day and ≥20 mg/kg total of conventional amphotericin, 2 to 3 mg/kg/day and 20 to 30 mg/kg total for a lipid-associated formulation.

Fluconazole (400 mg/d) has been shown to be as effective as IV amphotericin B in randomized trials in nonneutropenic patients[285] and has further been shown to be comparable to amphotericin B in observational studies of neutropenic patients with *Candida* IVDA BSIs[284] but should not be used in IVDA BSIs associated with septic thrombosis and high-grade candidemia or BSIs caused by azole-resistant *Candida* species.

Infections caused by fluconazole-resistant organisms, such as *Candida krusei* and *Candida glabrata*, have become an all too common phenomenon, with many centers reporting that 50 percent of their *Candida* isolates are non-albicans species that are usually resistant to azoles.[286] In these centers, fluconazole may not be the best drug to use for the initial therapy of healthcare-associated yeast BSIs, pending identification of the infecting species. Moreover, the toxicity of amphotericin B has prompted a search for new classes of antifungals. The echinocandins are novel antifungals that inhibit the synthesis of -1,3-glucan, a component of fungal cell walls.[287] Caspofungin, the first drug approved from this class, was recently shown to be at least as effective as IV amphotericin B in a prospective randomized double-blind trial in patients with deep *Candida*infections, most of whom had candidemia;[288] most notably, caspofungin was associated with a greatly reduced rate of study drug withdrawal because of adverse events (2.6 percent versus 23.2 percent; $p \equiv .003$). An intravenous echinocandin, which as a class has a low incidence of side effects, can be considered a first-line drug for the initial treatment of IVDA BSI caused by yeasts in centers with high rates of infection caused by non-albicans species, pending identification and susceptibility of the bloodstream isolate.

All patients with a IVDA BSI must be monitored closely for at least 6 weeks after completing therapy, especially if they have had high-grade bacteremia or candidemia, to detect late-appearing endocarditis,[245,289,290] retinitis,[289,291] or other metastatic infection, such as vertebral osteomyelitis.

International Perspective

Rates of IVDA BSI in resource-poor countries often are considerably higher than those seen in hospitals in most developed countries.[292] Many of the novel technologies discussed in this chapter, including anti-infective-impregnated catheters and antimicrobial lock solutions are not viable options for the prevention of IVDA BSIs in resource-poor countries. Nevertheless, an increasing number of studies from resource-poor countries have demonstrated that nontechnological approaches to prevention can result in substantial reductions in rates of IVDA BSI.[293,294,295,296] The results of these and other studies suggest that a large proportion of bloodstream infections can be prevented by changes in HCP behavior; thus, significant reductions in IVDA BSIs should be achievable, even in the absence of new medical technologies.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Infections in Indwelling Medical Devices

Author(s): Elicia Greene, RN, MS, CIC
Assistant Chief, Infection Control

Central Texas Healthcare System
Temple, TX

Chetan Jinadatha, MD, MPH
Assistant Professor, Texas A & M Health Science Center

Chief, Infectious Diseases Division
Central Texas Veterans Health Care System
Temple, TX

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Abstract

Modern medicine has made amazing strides during the past several decades, owing to improved medical knowledge and advanced applied technology. The enormous increase in the use of rather traditional and new innovative medical devices has saved numerous lives and improved the quality of life for many people. With the use of these devices has come the increased risk of serious infectious complications, particularly for critically ill patients who are growing in number, who are already at increased risk for infection, and who are most likely to use medical devices. Continued medical progress promises to bring an ever-increasing use of implantable prosthetic devices for a growing number of indications. Optimal prevention, diagnosis, and management of infections related to the use of these devices are of paramount importance to diminish major morbidity and mortality. This chapter addresses current issues in the prevention and management of infections in various implanted medical devices seen in current clinical practice, with a focus on select permanent devices seen in the inpatient arena. Indwelling medical devices that are of a more temporary nature such as vascular catheters, urinary catheters, or endotracheal tubes are not the focus of this chapter and are addressed in other chapters.

Key Concepts

• Implanted medical devices have an important role in healthcare to preserve and replace failing "natural parts" (e.g., hips, knees, valves). The risk of infection and the benefit of having the reusable medical device must be assessed.

• Infections of implanted devices result from the interaction of factors associated with the type of device being placed, the organism involved, and host factors.

• In general, such infections commence in one of three usually distinct manners: introduction of the microorganism at the time of surgical implantation, contiguous spread from postoperative wound infection, or by hematogenous seeding of the device from transient bacteremia or fungemia after the device has been inserted. Optimally, targeting these three pathways minimizes infection risks.

• Minimizing infections at the site of the closed incision and at remote sites after surgery are vital to maintaining an uninfected device. Rapid healing of the skin incision without drainage or hematoma formation reduces risk for deeper infection.

• Devices with endovascular implantation carry a risk of infection during episodes of bacteremia. *Staphylococcus aureus*bacteremia in a patient with such a device prompts an immediate evaluation to determine whether the device is infected. Efforts to minimize intravascular lines, when not required, will reduce this risk.

• Recent public awareness of the danger of healthcare-associated infections has expanded the role of the infection preventionist. Focus from accreditation agencies, reimbursement entities, and Congress has brought increased attention to the prevention of infections associated with implanted medical devices.

Background

The number and use of implantable medical devices inserted annually in the United States is quite remarkable and growing annually (Table 35-1).[1]Uses of implanted devices have greatly improved the quality of life for an increasing number of patients.[2]However, each device has its own risk of infection and subsequent attributable morbidity and mortality. Although orthopedic fracture fixation and joint prostheses generally have low rates of infection and attributable mortality, if infected, they can be generally difficult to manage, requiring multiple procedures and extended antimicrobial courses. Additionally, they are associated with significant morbidity such as amputation. More recently, prosthetic joint infections (PJIs) are now publically reported and thus under added scrutiny to prevent these infections.[3]Infections from devices placed intravascularly, including vascular grafts, pacemakers, mechanical heart valves, and ventricular assist devices, can be potentially life threatening and carry relatively high mortality rates. Infections in mammary or penile implants generally do not cause significant mortality but can psychologically cripple the affected individual due to their potential for disfigurement.

Table 35-1 . Clinical and Economic Consequences of Infections Associated with Surgical Implants*

Implant	Implants Inserted in the U.S. Annually	Projected Infections of Implants Annually	Average Rate of Infection†	Preferred Practice of Surgical Replacement	Estimated Cost of Combined Medical and Surgical Treatment

		no.	*%*	*no. of stages*	*U.S. $*
Cardiovascular					
Mechanical heart valve	85,000	3,400	4	1	50,000
Vascular graft‡	450,000	16,000	4	1 or 2	40,000
Pacemaker- defibrillator	300,000	12,000	4	2	35,000§
Ventricular assist device	700	280	40	1	50,000
Orthopedic					
Joint prosthesis	600,000	12,000	2	2	30,000
Fracture-fixation device¶	2,000,000	100,000	5	1 or 2	15,000
Neurosurgical-ventricular shunt	40,000	2,400	6	2	50,000
Plastic-mammary implant (pair)	130,000	2,600	2	2	20,000
Urologic –Inflatable Penile Implant	15,000	450	3	2	35,000

*The information is from published studies, market reports, and data provided by medical and surgical organizations, physicians, and device-manufacturing companies. The average costs reflect the usual charges by private institutions (taking into consideration that portions of the antibiotic courses, particularly prolonged courses, are sometimes administered in an outpatient setting) and exclude loss of income because of infection.

†The average rate of infection refers to initially inserted implants, which are less likely to become infected than replacement implants. For mechanical heart valves, the average rate refers to the incidence of prosthetic-valve endocarditis within 60 months after implantation. For ventricular assist devices, it refers to infections documented within three months after implantation, and for ventricular shunts, it refers to infections in adults and children, even though children are more likely to become infected.

‡The average rate of infection of vascular grafts refers to arteriovenous, femoropopliteal, and aortic grafts combined.

The average cost of treatment refers to infections associated with all three types of vascular grafts.

§The average cost of treatment represents a weighted average of the costs of treating infections of pacemakers ($25,000)

and pacemaker–defibrillator systems ($50,000); the difference in the cost of treating infections of these two systems is largely attributed to the difference in the average cost to a hospital of a pacemaker ($5,000) and a pacemaker–defibrillator system ($30,000).

¶Fracture-fixation devices include intramedullary nails, external-fixation pins (which are more likely to become infected than intramedullary nails), plates, and screws. A one-stage procedure is usually performed in patients with bone union, and a two-stage procedure in the absence of bone union. The average cost of treatment refers to infections associated with the various types of fracture-fixation devices. Treatment of infections of intramedullary nails is more expensive than treatment of infections of external-fixation pins (average costs, $25,000 vs. $5,000).

Adapted from Darouiche RO. Treatment of infections associated with surgical implants. *N Engl J Med*2004 Apr;350(14):1423.

Microorganisms attach to surfaces of inanimate material and produce extracellular polysaccharides, resulting in the formation of biofilms. Biofilms themselves facilitate further attachment and matrix formation, eventually resulting in an alteration in the phenotype of the organism with respect to growth

rate and gene transcription.[4] Organisms within a biofilm behave differently than do their free-floating counterparts. There exists an alteration of gene and protein expression that allows for increased survival of the organism in the biofilm.[5] Genes are turned on and off by quorum sensing mechanisms allowing microbes to sense population density, thereby making a "behavioral" decision in the development of biofilm formation.[6,7,8] The types of organisms that develop biofilms are broad, including many pathogenic bacteria and fungi.

Biofilm production begins with the attachment of the organism and the substratum of the device. Devices with a substratum that is rougher, more hydrophobic, acquires a proteinaceous conditioning film, or favorable electrostatic interactions tend to develop biofilms more rapidly than others.[9] Similarly, microbes whose cell surfaces are hydrophobic or have flagella, pili, fimbriae, or glycocalyx tend to develop biofilms more readily.[10] Once cells attach to the surface of devices, cell division occurs, as does the development of extracellular polymers made of polysaccharides that provide the matrix for the biofilm. Microbes that are embedded in the biofilm tend to divide at a slower rate,[11] but can intermittently detach and disseminate elsewhere to cause systemic infection.

Organisms associated with biofilm production enjoy a significant decrease in antimicrobial susceptibility, sometimes estimated to be from 10 to greater than 500 times the previous minimum inhibitory concentration or minimum bactericidal concentration.[12,13] Several explanations have been developed to explain this phenomenon.[4] The extracellular polymeric substances comprising biofilms can retard the diffusion of antimicrobials by chemically reacting with them or by limiting their rate of transport to the organisms. In addition, because the cells in the biofilms are dividing at a slower rate, the antimicrobial agents act on these cells more slowly. Acquired resistance by plasmid transfer between organisms can more likely be facilitated in the biofilm environment due to the higher probability of contact between cells and less disruptive shear forces to the cellular contacts. As the biofilm ages, the organisms associated with it tend to be less susceptible to antimicrobial agents. Another concern is the lack of available testing for the susceptibility of the organisms attached to biofilms by standard microdilution testing. In addition, the sublethal concentrations of antibiotics themselves, which are less able to permeate a biofilm, also predispose to resistance.

Patients receiving implanted medical devices are at increased risk of developing an infection at the surgical site. The increased risk of infection is linked to a localized immunological deficit at the interface between the implant and the host. This immune deficiency leads to a reduced ability to clear microorganisms from the vicinity of the biomaterial, and any contaminating bacteria are therefore more likely to cause an implanted medical device infection. Any foreign body may promote inflammation at the surgical site and may increase the probability of surgical site infection (SSI) after otherwise benign levels of tissue contamination.[14] Microorganisms commonly attach to living and nonliving surfaces, including those of indwelling medical devices. The distinguishing characteristic of biofilms is the presence of extracellular polymeric substances, primarily polysaccharides, surrounding, and encasing the cells.[15]

Multiple methods to prevent biofilm formation are being researched at the cellular level. Current topics of research to address biofilm production include genetic encoding to address adhesion, virulence, and biofilm formation. A second area of research is targeting the bacterial cell-to-cell communication using quorum-sensing inhibitors, focusing on theoretically suppressing infections caused by any staphylococcal strain, including methicillin and vancomycin resistance. Such strategies may have a future as alternative or adjunct therapy. A third area of research targets the use of bacteriophages in the controlling of

biofilms. Bacteriophages are viruses that infect bacteria. Engineering of enzymatic bacteriophages to prevent the colonization and subsequent infection may be applicable with urinary or intravascular catheters to reduce biofilm production.[16] Biofilm formation is a complex area of science. Refer to **70. Biofilms**, for more information.

Basic Principles

Although written in 1999, the Centers for Disease Control and Prevention (CDC) *Guideline for Prevention of Surgical Site Infection* is still a valuable reference for the overall management of the surgical patient receiving an implanted medical device. This guideline provides both an overview with detailed discussion of the pre-, intra-, and postoperative issues related to SSI and recommendations for prevention. The guideline represents the consensus of the Hospital Infection Control Practices Advisory Committee regarding the strategies for the prevention of SSI.[14] These measures are also outlined in **37. Surgical Site Infection**.

Infections of devices implanted in individuals result from the interaction of factors associated with the type of device being placed, the organism involved, and host factors. In general, infections associated with implantable devices commence in one of three usually distinct manners: introduction of the organism at the time of surgical implantation, contiguous spread of postoperative wound infection, or hematogenous seeding of the device from transient bacteremia or fungemia after the device has been inserted. Optimally, prevention efforts that target these three pathways minimize infection risks.[14]

The microbial involvement in device-associated infections is determined by both the properties of the organism and by the route of acquisition of infection. Gram-positive bacterial infections, especially *Staphylococcus epidermidis* and *Staphylococcus aureus,* typically comprise the majority of infections. Both of these organisms have developed means for binding and adhering to devices and biofilms. They also comprise the normal flora of the epithelial integumentary system and therefore have opportunity to be introduced to the device at the time of surgery or soon thereafter, if delayed wound healing or postoperative wound infection develops. Gram-negative bacterial and fungal infections comprise a lesser proportion of infections related to devices because they typically comprise a smaller proportion of our skin flora. Many times these organisms cause infection at some time after the device has been placed, even though they still comprise a minority of the pathogens observed.[14]

Host factors can increase risk for certain device-associated infections. Individuals with the potential to have poor or delayed wound healing, such as those with diabetes mellitus, taking systemic corticosteroids, in poor nutritional status, with irritative skin conditions (severe eczema or psoriasis), or who are obese, are believed to have an inherently higher risk of infection, despite lack of consistent evidence across all implanted devices. Those who have previously undergone a procedure at the same site are at higher risk for infection because the complexity of the surgical procedure results in longer operative times, longer duration for wound healing, increased risk for hematoma formation, and an environment where a previous disruption of the local lymphatic system can facilitate postoperative wound infections. Individuals with an unrecognized or untreated remote infection, such as a thrombophlebitis or urinary tract infection, carry a risk of hematogenous dissemination of infection and seeding of the device, even in the perioperative period, due to the presence of intraoperative urinary and intravascular catheters.[14]

For more than a decade, there has been a concerted effort from regulatory, governmental, private, and consumer groups to address adverse events related to infections. In 2008, the Association for Professionals in Infection Control and Epidemiology, the Society for Healthcare Epidemiology of America, Infectious Diseases Society of America, and others partnered to develop a compendium of evidence-based strategies to combat healthcare-associated infections (HAI). One focus area is on the prevention of SSIs.[17] Prevention bundling checklists were soon adopted by accreditation agencies such as The Joint Commission. In 2009, acute care hospitals were encouraged to adopt such evidence-based strategies through implementation of National Patient Safety Goal 7, Prevention of HAI. This is an example of how evidence-based practices are infused into our surgical practice. Specific elements of performance are outlined in the safety goal to measure the success of implementation and improve outcomes. The challenges we face in the management of infected implanted medical devices are in three major categories: prevention, diagnosis, and treatment. Prevention measures are addressed in depth at the end of the chapter.

Clinical Manifestations and Management

IMPLANTABLE JOINTS

The success of prosthetic joint replacements has led these procedures to become rather common, with hundreds of thousands of patients receiving joint prostheses annually.[18] As life expectancy increases, the number of elective arthroplasties performed each year will also increase. Projections show that by 2030, the number of patients receiving total joint arthroplasty procedures will be around 3.5 million. This is a 673 percent increase compared to 2005. Specifically, studies have projected an increase of more than 600 percent in the number of total knee arthroplasty procedures that will occur over the next few decades, while the number of primary total hip arthroplasties will increase 174 percent to 572,000 annually.[19,20] Infections associated with prosthetic joints occur less frequently than do aseptic failures but carry a high morbidity and substantial cost. Reported infection rates for primary total hip arthroplasty are between 0.3 and 1.7 percent and for primary total knee arthroplasty are between 0.8 and 1.9 percent. Rates tend to vary between 1.5 and 2.5 percent, but significantly higher rates are seen after revision procedures.[21] Highest incident infection rates are seen in the initial postoperative year and drop off substantially in subsequent years after implantation.[22] Removal of the prosthesis is usually required, with the cost of treating a single septic prosthetic joint being conservatively estimated between $68,000 and $107,000.[23] As a result, patients not only realize substantial financial expense, but also face the possible prospect of multiple surgeries requiring hospitalization and possible disability. Risk factors identified for PJIs include prior surgery at the site of prosthesis, immunocompromised states, rheumatoid arthritis, diabetes mellitus, poor nutritional status, obesity, psoriasis, extreme age, remote infection, and long-term urinary catheterization.[24]

PJIs can be classified in relation to time of onset after surgery.[25] This can provide a framework from which to understand the main pathogenesis of infection of the prosthesis and influence therapeutic options. Early infection is typically defined as manifestation of infection at the implant site during the first 3 months after surgery. However, some like to distinguish infections during the first 2 to 4 weeks because such infections may have therapeutic implications. This type of infection usually results from perioperative inoculation and generally is caused by virulent microorganisms. Clinical manifestations include local pain, erythema, edema, fever, and wound secretion. Delayed infection is defined as

manifesting itself 3 to 24 months after surgery. It is typically a low-grade infection, usually with low-virulence microorganisms. Clinical signs are subtle, if present. Persistent joint pain may be the only presentation, making it difficult to distinguish from aseptic failure of the joint. Late infection is defined by manifesting itself more than 2 years after surgery. Many of these infections are presumed to originate from hematogenous seeding from transient bacteremia from other sources. Infections caused by *S. aureus*, β-hemolytic streptococci, and occasional aerobic Gram-negative bacilli are more likely to produce a more fulminant infection. Coagulase-negative staphylococci and *Propionibacteriumacnes*are more likely associated with indolent infections.

There are no standardized criteria or single diagnostic test to define PJI. The diagnosis may be difficult in individuals presenting with only a painful prosthetic joint. Infection should be differentiated from other noninfectious causes of a painful joint, including hemarthrosis, bland loosening of the prosthesis, and other inflammatory causes of joint pain. A combination of clinical findings, laboratory results, microbiology, histopathology, and imaging studies is usually required for the diagnosis of infection.[26]

Leukocytosis, erythrocyte sedimentation rates, and C-reactive protein levels are also inadequate in this setting, even though they can generally be monitored in patients to guide response to medical therapy.[27,28]Plain radiographs may reveal loosening or dislocation of the prosthesis as well as cortical bone resorption or periosteal reaction. However, these changes can be seen in both septic and aseptic processes and may require months for them to be seen.[29]Technetium bone scans, gallium scanning, and indium-labeled leukocyte scans can be quite sensitive but relatively nonspecific and thus cannot by themselves confirm the presence of infection.[30]Likewise, bone scans may remain positive for as long as 6 months after implantation due to periprosthetic bone remodeling. Computed tomography (CT) scanning and magnetic resonance imaging are limited by imaging artifact from the implant itself. Positron-emission tomography with fludeoxyglucose F18 is currently being investigated for implant imaging but still is in its developmental phase.[31][32][33]Culture of a superficial wound or sinus tract often represents colonization from the surrounding skin and thus can be misleading. Prosthetic joint aspiration of synovial fluid for evaluation of leukocyte count and differential as well as Gram stain and culture provides a potential simple, rapid, and accurate test for distinguishing PJI from aseptic joint failure. This may represent the best manner for preoperatively diagnosing infection and potentially providing valuable microbiologic information to guide future medical therapy. Ideally, aspiration should occur prior to any antimicrobial therapy to improve the diagnostic yield of the study. Interestingly, the number of leukocytes needed to suspect PJI is less than that of septic arthritis from native joints. In prosthetic knee infections, a synovial fluid leukocyte count of greater than 1.7 × 10^9cells/L and differential greater than 65 percent neutrophils has a sensitivity for infection of 94 and 97 percent, with a specificity of 88 and 98 percent, respectively.[34]

Histopathological examination and cultures of periprosthetic tissue obtained intraoperatively are the best ways of making a diagnosis of PJI if it cannot be made preoperatively.[35,36] Three or more intraoperative samples should be obtained, ideally with no antimicrobial therapy given within the preceding 2 weeks. Sensitivity of periprosthetic tissue culture for the detection of the microbial pathogen ranges from 65 to 94 percent.[37]Histopathologic examination of the tissue has a sensitivity of greater than 80 percent and specificity of greater than 90 percent.[38]Because infections in implants involve microbial biofilms, techniques involving processing the removed explanted foreign material using sonication have been used to disperse adherent bacteria. A prospective trial comparing traditional tissue cultures and cultures obtained by sonication of explanted hip and knee prostheses revealed greater sensitivity with sonication

without significant loss of specificity.[39] There was even a more dramatic improvement in sensitivity in patients who had received antimicrobial therapy within the preceding 2 weeks.

The management of the infected prosthetic joint has not been standardized, although the ultimate goal is a long-term, painless, and functional joint.[40] The optimal approach to the management of infected arthroplasty depends on the clinical scenario and is an individualized process that requires a combination of medical and surgical therapy. Variables to consider include the type of infection, the causative microbe, stability of the prosthesis, medical comorbidities, and surgical limitations. One must realize that antimicrobial treatment in an implant-associated infection without proper surgical intervention usually fails. Early diagnosis can be crucial in determining treatment type and success rate. A management algorithm has been published to choose optimal surgical intervention according to clinical criteria.[41,42]

Replacement of the prosthesis can be performed as a single-stage exchange or as a two-stage exchange. There are no prospective trials comparing the two surgical procedures. The single-stage revision involves removal of the foreign material and reimplantation of a new prosthesis during the same operation, usually with antibiotic-impregnated cement. This allows for earlier mobility and less surgical risk due to a single procedure, but the risk of failure is greater. If the patient population is chosen appropriately and sensitive and less virulent organisms are involved, a success rate of greater than 80 percent can be achieved.[43] The two-stage exchange is considered the standard in the treatment of infected prosthetic joints because it generally has a success rate of greater than 90 percent.[42,43]

Antibiotic-impregnated cement spacers are commonly used after prosthesis removal to facilitate delayed reimplantation. Reimplantation of a new prosthesis is performed after completion of the antimicrobial course, which may be at least 6 weeks or longer in most cases. Antimicrobial-impregnated cement is commonly used in the implantation of prosthetic joints, but its efficacy is questionable because its use has not been subjected to controlled trials.[44]

The recent Infectious Diseases Society of America guidelines on the management of PJI suggest a third treatment strategy that involves open debridement without removal of the infected prosthesis done via open arthrotomy or arthroscopy. The open arthrotomy, which has been described to have a higher success rate than arthroscopy (up to 100 percent), involves extensive debridement and polyethylene line exchange followed by 6 to 8 weeks of intravenous (IV) antibiotics and long-term oral antibiotic suppression. Careful consideration should be given to the patient population chosen to undergo such a procedure. The patients should have no more than 3 weeks of symptoms with well-fixed prosthesis, absence of sinus tracts, and availability of susceptible oral antimicrobial agents for long-term suppressive therapy to follow the IV antibiotics. Failure to follow the stringent selection criteria leads to failure of intervention, wastage of resources, and the patient may suffer from more serious complications as compared to moving on directly to a two-stage procedure.[45]

Surgical intervention of any kind may be contraindicated due to surgical or medical conditions or patient refusal. In this scenario, lifelong suppressive antimicrobial therapy can be considered to suppress the infection and attempt to retain joint function.[46] Some success can be achieved with this approach if the infecting organism is relatively avirulent and highly susceptible to oral antimicrobials, the patient is not systemically ill, and the prosthesis is not loose. High rates of failure are seen with this approach, not to mention the possibility of increasing antimicrobial resistance and side effects from chronic antimicrobial administration.

There are no universally agreed standards for antimicrobial therapy in the management of PJIs. Ideally, the antimicrobial agent should have bactericidal activity against the slow-growing, surface-adhering, biofilm-producing microbes.[35] No consensus exists for choice, route, and duration of antimicrobial therapy. Therefore, while most agree that longer courses (6 weeks or greater) of therapy are required for chronic infections and in those with more difficult-to-treat microorganism, some advocate for shorter courses in specific situations.[42] There is some evidence for the role of rifampin in combination therapy for staphylococcal infections in this setting.[47]

Preventative measures are necessary to decrease the rate of PJIs. The following strategies are divided into three areas: host, operating room environment, and surgical variables. Some strategies are strongly supported in the literature for the prevention of all SSIs.[14] Successful screening of the host or recipient for optimization is the first consideration in the prevention of PJIs. Screening provides an overall picture of health and should include medical history background to reveal any underlying conditions. Previous diagnosis or medications may determine risk, such as medications related to rheumatoid arthritis or malignancy. Optimizing health through nutritional evaluations is important; obese patients with weight >20 percent above ideal weight are at greater risk of developing an infection. Patients on anticoagulants are at greater risk, as hematomas are one of the most important predisposing factors for PJIs. After the medical history is complete, a thorough clinical evaluation should be conducted. Patients who are smokers should complete a smoking cessation program prior to operation.[48] Any clinical signs and symptoms, such as ulcerations, neuropathy, or skin issues, may predispose the patient to higher risk for infection. Preoperative blood work should involve screening for diabetes, increased risk of bleeding or hematoma, and malnutrition.

Prevention measures should address the operating room environment, including the cleanliness of operating room surfaces, air quality, amount of traffic, health of operating room personnel, proper hand hygiene,[49] and use of triple sets of gloves, where the outer set of gloves is changed following draping. Changing gloves at regular intervals can decrease the incidence of bacterial contamination. Skin preparation of the patient is very important and should begin at home preoperatively. Since the primary source of bacteria in the operating room is related to the personnel, following the stringent preventative strategies is important in the successful prevention of PJIs.

Surgical factors when closely managed decrease the risk of overall PJIs. There is good evidence to support skin preparation as a means of preventing PJIs. Preoperative showers using betadine or chlorohexadine wipes have been suggested prior to surgery; however, the utility of this practice is questionable. A recent systematic review of randomized controlled trials comparing preoperative full-body bathing or showering with any antiseptic preparation to non-antiseptic preparations or placebo to reduce SSI found no clear evidence of benefit. The authors included seven trials with a total of 10,157 participants. The antiseptic used in all the trials was 4 percent chlorhexidine gluconate. Only one large study found a statistically significant difference in favor of bathing with chlorhexidine when compared to no preoperative bathing.[50]

Hair removal from the incision site should be performed before entering the operating room using clippers. Preoperative (30 to 60 minutes prior to insertion) administration of prophylactic antibiotics has been shown to prevent infections.[51][52][53] Evidence supporting the use of antibiotic irrigation at time of joint replacement, and antibiotic impregnated bone cement or beads is on the rise.[54,55]

PROSTHETIC CARDIAC VALVES

Prosthetic valve endocarditis (PVE) is a potentially fatal complication of cardiac valve replacement surgery. The incidence of PVE is greatest during the initial 6 to 12 months after surgery and then drops to a continuous low level thereafter .[56]Within 5 years of a prosthetic valve surgery, 3 to 6 percent of patients would have developed a PVE. The rate of infection appears to be similar whether the prosthesis is in the mitral or aortic position. Among patients with *S. aureus*PVE, mortality of 40 percent or higher has been reported.[57]Other predictors of mortality include HAI, persistent bacteremia, heart failure, intracardiac abscess, and stroke.[58]PVE can be defined as early if occurring within 12 months of valve replacement and late if occurring after 12 months has elapsed. The pathogenesis and microbiology differ between the two.[59]Those defined as early are more likely to be acquired in the perioperative period, either in the operating room or in the immediate postoperative period through infections in incisions, vascular and urinary catheters, or other healthcare-associated sources. This can also lead to transient bacteremia. As a result, coagulase-negative *Staphylococcus*and *S. aureus* are the predominant pathogens. Late cases of PVE are more typically acquired in the community and microbiologically resemble pathogens seen in native valve endocarditis. Organisms generally cannot adhere on leaflets of mechanical prosthetic valves because they are free of thrombotic material.[60]Hence, early infections frequently involve the junction of the sewing ring and annulus, leading to valve dehiscence and paravalvular abscess.[61,62]Bioprosthetic valve infections usually present later and are more frequently located on the leaflets due to degeneration of the cusps, leading to cusp rupture, perforation, and vegetation.The incidence of PVE is approximately 0.5 percent per patient-year, even with appropriate antibiotic prophylaxis. PVE is associated with very high mortality rates (30 to 50 percent).[63]

The diagnosis of PVE may be difficult, especially early after surgery, because the clinical picture can be atypical and nonspecific.[64]The diagnosis relies predominantly on the combination of positive blood cultures and echocardiographic evidence of prosthetic infection, including vegetations, periprosthetic abscesses, or a new paravalvular regurgitation.[65]Transesophageal echocardiogram is highly sensitive in detecting these abnormalities.[66]Fever is seen in more than 95 percent of cases. In evaluating any febrile illness in a valve recipient, a high index of suspicion for PVE must be maintained and serial blood cultures should be drawn. Cardiac findings, such as a new or changing murmur, new onset conduction abnormalities, or congestive heart failure, can be clues to the diagnosis of endocarditis. Other embolic or immunologic phenomena, such as conjunctival hemorrhages, Roth spots, splinter hemorrhages, Janeway lesions, Osler nodes, and larger embolic phenomena, lend support toward the diagnosis, but their absence does not exclude one. Other findings may include splenomegaly, anemia, leukocytosis, and hematuria.

The diagnosis of PVE depends on the clinician's high index of suspicion, multiple positive blood cultures, recognition of clinical presentation, and echocardiography findings. Not all need to be present for the diagnosis. The Duke criteria for the diagnosis of endocarditis have provided a schema that has correlated strongly with pathologically confirmed cases,[67,68]but with lower sensitivity than is seen in native valve infection.[69]Persistently negative blood cultures can be seen in individuals with PVE. Such cases can be seen in infections caused by fastidious organisms or others that may be difficult to culture, including the HACEK group (*Haemophilus aphrophilus, Actinobacillus actinomycetemcomitans, Cardiobacterium hominis, Eikenella corrodens, Kingella kingae*), *Coxiella burnetii, Bartonella* spp.,

*Candida*spp., and others. Echocardiography is vital not only for the diagnosis of PVE,[70]but also to assess valve function and to identify possible areas of abscesses and sites of dehiscence that may warrant surgical intervention. The transesophageal approach is superior to the transthoracic approach,[71] but both can provide critical information in many cases. Nondiagnostic echocardiography is insufficient to exclude the diagnosis of endocarditis. Blood cultures should be incubated for 3 to 4 weeks in cases of culture-negative endocarditis to try to recover fastidious organisms. Some infections can be diagnosed only with serology or polymerase chain reaction techniques of valve material removed at surgery or by specialized stains on pathology material .[72]

Medical therapy for PVE traditionally employs the use of high doses of bactericidal antimicrobials based on the in vitro susceptibilities of the etiological organism. Synergistic and bactericidal agents should be used when possible for at least 6 weeks. When blood cultures have already been drawn but are still negative, empirical therapy for clinically apparent PVE should at least include vancomycin and gentamicin because staphylococci, streptococci, and enterococci represent the majority of pathogens implicated. Ceftriaxone or another comparable third-generation cephalosporin can be added if infections due to HACEK organisms are suspected. In cases where infection is indolent and the patient is hemodynamically stable, antibiotics can briefly be withheld, pending the isolation of the organism from blood culture. Patients should be monitored for fever, resolution of positive blood cultures, embolic complications, intracardiac complications, development of congestive heart failure, and complications due to antimicrobial therapy.Despite prompt and appropriate antibiotic treatment, many patients with PVE will eventually require surgery. Medical treatment alone is more likely to succeed in late PVE (occurring >6 months after surgery) and in nonstaphylococcal infections.[56,58,69]

Indications for surgical intervention in PVE have evolved over time and still have some uncertainties.[73,74,75]Surgery should be considered in the following situations: failure of medical treatment; hemodynamically significant prosthesis regurgitation, especially if associated with deterioration of left ventricle function; large vegetations; and development of intracardiac fistulas.[56,58,76]Patients with moderate or severe congestive heart failure as a result of valve dysfunctiontypically will not survive without surgery. Those with an unstable prosthesis, paravalvular infection, and uncontrolled or relapsing infection while on appropriate therapy also require surgery. Some have noted that the mortality associated with some organisms, most notably *S. aureus* and *Candida*spp., is so great with medical therapy alone that early surgical intervention is warranted as well in these cases. However, others counter that those with uncomplicated *S. aureus*PVE can be treated successfully without surgery.[77]Some consider large (>10 mm) hypermobile vegetations as a relative indication for surgical intervention,[78]but it has not yet been shown that early surgical intervention prevents emboli or reduces morbidity or mortality. Those with cerebral emboli due to vegetations have demonstrated a worse outcome with cardiac surgery. Generally, a combined medical surgical strategy is thought to be the best strategy in those with complicated PVE, although mortality remains high.[77]Both mechanical prostheses and homografts (bioprostheses) can be surgically utilized in the treatment of PVE.[73]Homograft valves tend to be more ideally suited for reconstruction of the aortic root, especially in the presence of prior root abscess. There appears to be little difference in long-term outcomes between mechanical and bioprosthetic valves.

Prevention of PVE is mainly dependent on appropriate antibiotic prophylaxis prior to an invasive procedure. Some of the procedures where prophylaxis is recommended include all dental procedures that involve manipulation of gingival tissue or the periapical region of the tooth or perforation of the oral

mucosa. It may be reasonable to administer infective endocarditis prophylaxis to a patient undergoing a respiratory procedure including bronchoscopy that involves incision and biopsy of respiratory mucosa. No prophylaxis is needed for gastrointestinal or genitourinary procedures unless a genitourinary procedure is being performed through infected tissue.[79]

DEFIBRILLATORS AND PACEMAKERS

In 2010, the American Heart Association published a scientific statement titled *Update on Cardiovascular Implantable Electronic DeviceInfections and Their Management*.[80]This review is a study of all aspects of cardiovascular implantable electronic device (CIED) infections. Since the original position paper in 2003, there have been exceptional advances in the understanding of cardiovascular device infections. CIEDs have become increasingly important in cardiac disease management over the past five decades in the United States and have dramatically improved both patient quality of life and life expectancy. The number of indications and placement of both cardiac permanent pacemakers (PPM) and implantable cardioverter-defibrillators (ICD) have increased over time.[81,82]As a result, more patients are being evaluated and managed for infections of these devices. There was a 124 percent increase in infections associated with cardiac devices between 1990 and 1999 .[83]Reported incident infection rates of these cardiac devices vary widely and range from 0.13 to 12.6 percent.[84]The cost of a CIED infection is difficult to estimate but considering the acquisition of a CIED alone, the costs are substantial. Even evaluation of a suspected *S. aureus*CIED infection can be expensive.[85]Reported risk factors linked to infections include congestive heart failure, diabetes mellitus, renal insufficiency, corticosteroid use, malignancy, multiple device insertions/revisions or generator exchanges, the use of a temporary pacing system at the time of implantation, remote infection at the time of insertion, and experience level of the person inserting the device.[86,87]However, not all studies have been consistent in supporting all these factors in contributing to the incidence of cardiac device infections.

PPM and ICD both consist of a generator surgically placed in a pocket in the subcutaneous or subfascial tissue of the chest wall or abdomen connected to electrode leads that can be placed in the intracardiac, intravascular, or epicardiac positions. The vast majority of leads are currently being placed percutaneously in the transvenous mode with the tips terminating in the right atrial and ventricular endocardium. Infections of these devices can be categorized into two types: those involving the generator pocket alone and those that involve the intravascular electrode, which later can involve the endocardial tissue, resulting in endocarditis. The distinction, if it can be accurately determined, is critical because the management and morbidity of these infections can be quite different.

The generator pocket is the most frequent site of infection involving PPM and ICD. The majority of these occur soon after generator placement or exchange, although a smaller number will occur sometime after implantation due to the device eroding through the subcutaneous tissue and skin. Early infection seen within weeks to months often is thought to arise from direct intraoperative microbial seeding of the device or pocket.[88]Late pocket infections can also occur from mechanical erosion through the skin with subsequent seeding of the pocket or from a chronic smoldering pocket infection.

Despite the low infection rate, hematogenous seeding of the device has also been implicated as a route of infection in these devices. Possible sources of the bloodstream infections include contaminated vascular catheters/devices and infections at other sites, including urinary, hepatobiliary, gastrointestinal, and respiratory sites. Both coagulase-negative staphylococci and *S. aureus*comprise the most common

organisms of these device-associated infections.[89,90] A prospective cohort of patients with implantable cardiac devices presenting with *S. aureus* bacteremia after 1 year of placement found that nearly 29 percent had infection involving the device.[91] A larger retrospective cohort study found the risk to be as high as 54 percent.[92] This emphasizes the high risk of bacteremic seeding of cardiac devices among patients with *S. aureus* bacteremia. Therefore, clinicians caring for patients with *S. aureus* bacteremia should maintain a high index of suspicion of implant infection, even if there are no other visible signs of device involvement. Conversely, patients with these devices in place who experience Gram-negative bacteremia very rarely are found to have cardiac device infections.[92,93]

The clinical presentation of infections involving PPM and ICD can be highly variable.[94,95] Many present with localized pocket erythema, pain, swelling, draining sinuses, or pocket erosion. Nonspecific laboratory abnormalities such as leukocytosis, anemia, and high sedimentation rate are present in less than one-half of infections.[90] Fever is seen in less than 20 percent of those with device infections, and bacteremia is seen in only a third of these, many of them without systemic symptoms. Persistent bacteremia, especially with *S. aureus*, should alert the clinician to a device infection. Echocardiography is a useful tool in the diagnosis of implantable cardiac device infections. Vegetations can be visualized on the electrode lead, tricuspid valve, or in other areas of the cardiac endothelium. Endocarditis should be considered in all patients with implantable cardiac devices and chronic fever, persistent Gram-positive bacteremia, and recurrent or persistent pocket infection.

Management of PPM and ICD infections is a challenge for both cardiologist and infectious disease specialists. A distinction between pocket infections alone versus deeper involvement, including the endovascular tissue, can be critical. CIED removal is not required for superficial or incisional infection at the pocket site if there is no involvement of the device. Seven to 10 days of antibiotic therapy with an oral agent with activity against *S. aureus* is reasonable.[90]

The 2010 update on CIED infections and their management recommends complete removal of all hardware regardless of the location (subcutaneous, transvenous, or epicardial) in patients with established CIED infections.[80] This includes cases in which a localized pocket infection occurs in the absence of signs of systemic infection. Complete removal of hardware is needed because infection relapse rates due to retained hardware are high.[90] Erosion of any part of the CIED should imply contamination of the entire system, including the intravascular portion of leads, and complete device removal should be performed. As newer technologies have emerged and the experience has grown, percutaneous lead extraction has become the preferred method for removal of CIED hardware. However, these procedures involve significant risks, including cardiac tamponade, hemothorax, pulmonary embolism, lead migration, and death, even in experienced hands. Thus, the performance of these procedures should be limited to centers with the appropriate facilities and training, which includes the presence and imminent availability of cardiothoracic surgery on-site to provide backup in the event of complications. In high-volume centers, percutaneous lead removal can be accomplished relatively safely with a high rate of success.[96]

Antimicrobial therapy is adjunctive in patients with CIED infection, and complete device removal should not be delayed, regardless of timing of initiation of antimicrobial therapy. Selection of the appropriate antimicrobial agent should be based on identification and in vitro susceptibility testing results. Because the bulk of infections are due to staphylococcal species, and some of them will be oxacillin resistant, vancomycin should be administered initially as empirical antibiotic coverage until microbiological results

are known. Patients with infections due to oxacillin-susceptible staphylococcal strains can be given cefazolin or nafcillin alone with discontinuation of vancomycin. Vancomycin should only be used in patients who are not candidates for β-lactam antibiotic therapy and those with infections due to oxacillin-resistant staphylococci. Pathogen identification and in vitro susceptibility testing can be used to guide treatment in other nonstaphylococcal CIED infections.

It is imperative that there be a new assessment conducted to review the need for reimplantation of the new device in each patient with an infected CIED. One third to one half of patients in some series will not require a new CIED placement. Removal of infected hardware should not be attempted until a careful assessment of a new implantation strategy has been performed, particularly in patients with pacemakers for complete heart block and resynchronization therapy devices.[97] Generally, 4 to 6 weeks of intravenous antimicrobials after device removal should be given in those with endocarditis or device-associated bacteremias.[1] Shorter courses of 10 to 14 days can be given in those with localized pocket infections.[72] If complete removal of the device is not possible, a longer course of antimicrobial therapy can be entertained, realizing the real risk for relapsing and persistent infection. Lifelong suppressive antimicrobial therapy should be restricted to patients who cannot have the device removed. Criteria include stable cardiovascular status, clinical improvement with initial antimicrobial therapy, and clearance of bloodstream infection.[60]

Prevention of CIED infection can be addressed before, during, and after the device implantation. Before device implantation, it is important to ensure that patients do not have clinical signs of infection. Parenterally administered prophylactic antibiotics are supported by a meta-analysis and are recommended 1 hour before the procedure.[98] Routine oral or IV antibiotic prophylaxis is not recommended for CIED infection prevention before any dental, gastrointestinal, genitourinary, or pulmonary procedures.[79]

LEFT VENTRICULAR ASSIST DEVICES

Left ventricular assist devices (LVADs) represent one of the major advances in the modern management of patients with end-stage heart failure, and have been shown to provide longer survival and better quality of life in these patients in comparison to traditional medical management. There are currently three approved indications for LVADs: bridge therapy to support cardiac function until cardiac recovery, bridge to cardiac transplantation, and as “destination therapy” or end-stage therapy to lengthen lives in patients with severe cardiac disease who otherwise are not cardiac transplant candidates.[99,100] Despite advances in the development of LVADs and the technical advances in placement and management of these devices, these patients are subject to serious risk of infection.[101][102][103][104][105][106] LVADs are electrical pump devices implanted through the mediastinum with an inflow cannula placed in the apex of the left ventricle and an outflow cannula anastomosed to the ascending aorta. Currently available LVADs are powered utilizing a driveline containing an electrical cable and air vent connecting the interior implanted pump to the exterior power pack. This driveline breaches the skin, providing a portal of entry for potential pathogens. Along with infections affecting the driveline exit sites, other notable complications include pocket infections involving the implanted device, superficial infections at the surgical site, and endocarditis as a result of LVAD infection. The incidence of infection generally increases with duration of support from the implanted device.[107] Infectious complications leading to sepsis remain a common cause of death prior to heart transplantation in individuals with LVADs. There are many risk factors that predispose to postoperative LVAD infections, including advanced age, prolonged cardiac cachexia, use

of immunosuppressive agents, malnutrition, renal failure, and HAIs.[108] In addition, poor wound healing due to diabetes, chronic debilitation, localized hematoma, and tension around the wound edges can cause local wound necrosis and infection.

All the LVAD components are susceptible to infection, each with their own specific characteristics and clinical implications. Diagnosis of LVAD infections can be problematic due to a lack of a universal definition. Infection can involve any aspect of the device—the surgical site, the driveline exit site, the device pocket, or the pump itself—leading to bacteremia, mediastinitis, and endovascular infectious complications such as endocarditis.[108] Driveline infection appears to be the most common type of infection, and this may be treated early with wound care and appropriate antimicrobial treatment. Erythema with or without seropurulent drainage may indicate exit site cellulitis; however, it can be difficult to distinguish infection from irritation of an inadequately immobilized driveline. Systemic manifestations such as fever and leukocytosis may or may not be present. Gram stain and culture of purulent drainage should be obtained, being careful not to deeply probe and disrupt the integrity of the exit site. While appropriate antimicrobial therapy and increased frequency of dressing changes may suffice for some exit site infections, one must realize that some patients may become systemically ill, with infection spreading deeper to multiple sites. LVAD pump pocket infections can occur as an extension of exit site infections or due to localized growth at the pump site. Localized abscess formation against the pump also can be aided by postoperative hematoma formation, providing an excellent medium for bacterial proliferation. Fever, pain, and localized swelling may occur, but initially the incision site may appear relatively unremarkable. Bacteremia from intravascular device infection can lead to sepsis with complications, including endocarditis, cerebral emboli, and multiorgan failure.[109] Determining whether the LVAD is the source of bacteremia is sometimes difficult because there may be other concomitant indwelling intravascular catheters present. Both LVAD and intravascular lines use similar criteria for the diagnosis of infection. If the same organism is found at the exit site or pocket of the LVAD and in the bloodstream, if the bacteremia is persistent especially after removal of all other lines, and if no other source is identified, then the diagnosis of an LVAD-associated bloodstream infection is made. Imaging with ultrasound or CT may assist in identifying pocket site infections or fluid collections. Transesophageal echocardiogram can be utilized to evaluate for device-associated endocarditis.

Treatment of infections involving LVADs can be very complex and has not been standardized. The devices are placed in individuals who are critically ill by definition, often malnourished, and with multiple supportive measures and vascular lines. Driveline infections can sometimes be managed solely with increasing dressing changes and wound care, but recurrences do occur.[105] Empiric antimicrobial therapy guided by Gram stain and culture of exit site purulence should be considered in many cases, with initial broad (especially Gram-positive) antimicrobial coverage administered prior to culture results. Pump pocket infections mandate drainage of abscess fluid along with antimicrobial therapy. After debridement, various approaches have been attempted in managing the chronic wounds that develop, including placement of antibiotic-impregnated polymethylmethacrylate beads in the pump pocket,[110,111] use of omental or muscle flaps,[112,113] and the use of vacuum-assisted closure devices at driveline sites.[114][115][116]

The duration of antimicrobial therapy needed to treat LVAD infections is unknown and individualized. For superficial driveline infections, antimicrobial therapy should continue until drainage stops and the site has healed. When deep endovascular and device-associated infection is suspected, antibiotics should be continued at least until the device is removed and sometime thereafter because serious infection may persist beyond explanation of the device. Removal of the device as a part of cardiac transplantation offers the best chance of cure, and ongoing infection may not adversely influence long-term transplant

survival in many cases.[117] Antimicrobial use in such patients tends to be excessive[104] because a typical strategy involves suppression of infection with definitive eradicative therapy administered after cardiac transplantation. This lends these patients to experience more resistant infections, including fungal infections.[118]

Regardless of the origin and which LVAD component is involved, LVAD infection is a serious complication that can be life threatening. In the REMATCH trial, infections accounted for 41 percent of the deaths observed in patients on mechanical LVAD support. Data in the study highlighted the importance of prevention and management of LVAD infections and bacteremia to improve and extend the survival benefit in LVAD patients, especially beyond the first year. Prevention of infections must become a central objective for hospital teams involved in the care of patients undergoing LVAD therapy. Measures should start even before the moment of the LVAD implantation and continue throughout the complete duration of mechanical support.[119]

TISSUE ALLOGRAFT IMPLANTS

Tissue allografts are being increasingly used in surgical procedures. Tissues commonly used include vascular grafts, cardiac homografts, corneas to restore eyesight, skin replacement for severe burn patients, and musculoskeletal tissue for a variety of orthopedic indications. Bone allografts are most frequently used to accomplish spine fusions, improve the quality of bone in revision hip and knee procedures, restore bone loss during trauma or after removal of tumors, and promote healing of fractures. Bone allografts also eliminate the need for a second surgery site to recover after an autograft. Tissue transplantation is a rapidly growing industry, with more than 1.5 million musculoskeletal tissue transplants alone done annually in the United States, and the number is rising annually.[120]

Infectious risks have been recognized with the use of human tissue. Creutzfeldt-Jakob disease (CJD) is discussed fully in **73. Creutzfeldt-Jakob Disease and Other Prion Diseases** of this text. It is noteworthy to include in this discussion that it has been recognized for more than 25 years that CJD can be transmitted by dura mater allografts.[121] Corneal tissue also has been implicated in the transmission of CJD.[122][123][124] Transmission of human immunodeficiency virus (HIV) has been documented by tissue implants, despite HIV-negative serology of the donor at the time of donation.[125] In addition, tissue allograft implantation has resulted in the transmission of Hepatitis B and C, human T-cell lymphotropic virus, rabies, herpes simplex virus, cytomegalovirus, fungi, and most recently West Nile virus.[120,126]

The CDC estimates 1 to 2 percent of recipients acquire an unexpected disease transmission, including malignancies, through an organ transplant.[127] Over the years, there have been well-publicized infections heightening the scrutiny of the tissue banking industry. A 23-year-old man underwent reconstructive knee surgery in November 2001 in Minnesota, using a femoral condyle allograft. Within 4 days, he developed shock and died. Findings revealed overwhelming bacteremia sepsis with *Clostridium sordellii* that eventually was traced to contamination of the tissue allograft.[128] Other bacterial infections resulting from musculoskeletal tissue grafts have been identified.[129,130] Investigation of the fatal case revealed that *C. sordellii* was found on tissue from the same donor that was not implanted. Still cited are the frequent transmissions related to allografts. In March 2002, the CDC had received a total of 26 reports of bacterial infections associated with musculoskeletal allografts.[129] Thirteen of these were

infected with *Clostridium*spp., and 14 were processed at a single tissue processor. Since 2003, although not confirmed as the source of infection in all cases, 36 (0.1 percent) patients with West Nile virus disease had received a blood transfusion or organ transplant within 30 days of illness onset.[131]

As a result of these events, tissue banks are under more scrutiny with respect to procurement, processing, and sterilization of all their human tissue allografts. Prior to 1993, tissue recovery, processing, and distribution were largely unregulated by the U.S. federal government. The American Association of Tissue Banks (AATB) has set forth guidelines and standards for tissue banking.[120]It also provides accreditation, certification of tissue banking personnel, and inspections of tissue banking organizations. Since 2005, the AATB has mandated that accredited tissue banks must screen cadaveric serum using nucleic acid testing for HIV and Hepatitis C. AATB's accredited tissue banks also use generalized screening questionnaires from donors or their families to identify donors of higher risk. However, many commercial tissue banks are not members of AATB. The U.S. Food and Drug Administration (FDA) has also finalized its requirements for current good tissue practice and has mandated new rules regarding the use of allogeneic tissue.[132]The CDC has advocated the use of ethylene oxide and gamma radiation[133]for sterilization of certain tissues, although it sacrifices some biomechanical properties of tendons.[128]Bacterial contamination of tissue during surgical removal from the cadaveric donor and subsequent processing can be minimized by following important steps suggested in guidelines. Culturing of tissue before and after processing and prior to implantation is standard practice, revealing when contaminated tissue should not be used and when patients may need prophylactic antibiotics after implantation.[133,134]

Prevention efforts related to tissue allograft implants will require further research into donor evaluations and standardization of data collection and repository. In May 2010, the FDA held a workshop entitled Emerging Infectious Diseases: Evaluation to Implementation for Transfusion and Transplantation Safety. The goals of this meeting were to identify the risk for transmission of donor-derived infections and develop guidelines for emerging infectious diseases.[135]

SPINAL IMPLANTS

Infections after spinal implantation pose serious diagnostic and therapeutic challenges. Spinal implant surgeries and subsequent infections are on the rise.[136]The overall incidence of spinal implant infections ranges from 1 to 12 percent.[137][138][139]Such infections can be of early onset (1 to 3 months) or late onset (>3 months) with incidence being 2.6 and 7 percent, respectively.[140]Implant-associated spine infections are usually caused by organisms that produce biofilms. The most common organisms are *S. aureus*, Gram-negative rods like *Escherichia coli*or*Pseudomonas aeruginosa*, *Propionibacterium*, enterococci, and coagulase-negative staphylococci.[140]The risk factors can be divided into four major categories: patient related risk factors, surgeon dependent risk factors, operative risk factors, and postoperative risk factors. The most common patient related risk factors are diabetes, immunosuppression, alcoholism, steroid therapy, nutritional status, and neuromuscular disease. The most common surgeon dependent risk factors include skin preparation, prophylactic antibiotic choice, and surgical trauma. The operative factors are prolonged surgery, prolonged retraction, bone grafting, implantation in itself, type of instrumentation, approach (anterior versus posterior), and a number of personnel in the operating room. The postoperative risk factors are prolonged postoperative bed rest, skin maceration, and presence of

drainage tubes.[137,138,140,141] Several other factors like hematoma, dural tear and usage of bone cement may have no role in development of infection.[140]

Spinal implant surgery complications can be divided into early and late complications.[140] Early complications include hemorrhage, hematoma, seroma, cerebrospinal fluid leak, infection, and hardware malposition. Further complications like hemorrhage can lead to neurological problems when neural structures are compressed, requiring emergent surgical decompression. Late complications may be related to infection or mechanical issues such as hardware failure or fracture, hardware loosening, and migration. There may be damage done to neighboring important structures such as major nerves or blood vessels resulting in a considerable secondary complication. Superficial infections tend to manifest earlier than deeper infections. The common presentations of infection include worsening pain, erythema, discharge, swelling, or failure of operative wound to heal. Many of the complications like hardware loosening or failure, malunion, malposition, nonunion, and even established osteomyelitis could be related to spinal implant infections and may be the presenting symptom. Other manifestations of infection could include pseudarthrosis, secondary degenerative changes, and osteopenia.[140141142143144145]

Plain films are routinely used for the follow-up of postoperative spine and should be used as a first-line imaging choice. The high spatial resolution of CT with three-dimensional multiplanar reformatting capabilities is an excellent tool for the assessment of the instrumented spine. Magnetic resonance imaging is probably the best modality of imaging because it provides excellent images of the contents of the spinal canal, soft tissues, postoperative collections, and neuronal impingements for damages and is particularly useful in early diagnosis and subsequent management of spinal implant infection and complications. Triple-phase bone scans are sensitive but not specific for infection. Tagged white cell scans can also be useful. 2-[^{18}F]-fluoro-2-deoxy-D-glucose positron emission tomography is superior to tagged white cell scanning with regard to diagnosis of chronic osteomyelitis. Ultrasound has a limited role in the evaluation of the instrumented spine.[146147148]

The management of an infected spinal implant is controversial and complicated. The treatment of spinal infection involves management of the implant/wound and antimicrobial therapy. Several studies have shown that early infections can be successfully managed with retention of the implant in situ and aggressive irrigation and debridement.[140] On the contrary, late-onset infections may require the removal of the implant. Removal of the implant may foster faster healing, but has been associated with significant complications like pseudarthrosis and loss of correction.

The usual course of antibiotics for early or late infections is 4 to 6 weeks of IV antibiotics and may require a follow-up oral course for 6 to 12 months, especially if there is retention of hardware with or without adequate debridement. Sometimes the hardware needs to be retained for the purpose of stability. Data is unclear about the necessity of using a bactericidal drug and about the ability of antimicrobials to penetrate bone. There is no consensus opinion about the use rifampin as an adjunct therapy for treatment of *S. aureus*infections.[140,143,145]

There is a 9.5 percent overall rate of contamination with spinal implants before insertion, which might explain why spinal surgeries with implants have a higher rate of infection as compared to spinal surgeries without implants. Further, if an implant in the operating room is covered with a sterile surgical towel, the contamination rate is 2.0 percent versus 16.7 percent for uncovered implants. Thus, covering spinal implants in the operating room may be a simple way to reduce contamination hence reducing infections.[149]

Prevention of Infections in Implants

Guidelines for the prevention of SSIs have been developed.[150,151] These same principles apply to the prevention of implantable device infections. Given the debilitating morbidity, possible mortality, and economic impact of implanted medical device infections, any preventive measure proven effective should be considered.

It is estimated that of the 42 million surgical procedures performed annually in the United States, as many as 40 percent involve surgical complications. The Surgical Care Improvement Project (SCIP) was formulated by a partnership of national organizations with a goal of reducing surgical complications by 25 percent by 2010. SSI is the third most common type of HAI.[152] Infections related to implanted devices can be devastating. In vascular surgery, graft infection remains a serious limb-threatening and often life-threatening complication.[153]

Steps to prevent infections in implants can be divided into those that occur before, during, and after implantation. Specific strategies include preoperative screening and risk reduction, skin preparation, correct hair removal if at all, maintenance of normothermia, appropriate use of antimicrobials, hand hygiene, a clean operating room environment, minimization of personnel traffic, correct filtration and flow of air, meticulous sterile technique, avoidance of hematomas, and promotion of a culture of safety and teamwork.

Preoperative screening protocols should include the patient's background medical history along with previous diagnosis, medication, and social/behavioral factors (rheumatoid arthritis, systemic steroids, weight >20 percent above ideal weight); clinical signs or symptoms observed by the clinician (hematomas, ulceration, and neuropathy); and, lastly, results of preoperative testing (elevated glucose, or low albumin). The combination of all three categories reveals necessary information needed to develop and implement a specific and individualized strategy for patient optimization.[154]

The preoperative preparation of the patient undergoing implantation reduces the modifiable risk factors inherent to the host. Whenever possible, identify and treat all infections remote to the surgical site before elective operation. Otherwise, elective operations should be postponed on patients with remote site infections until the infection has cleared. It is advisable to definitively treat existing dental or gingival disease in patients who are undergoing elective procedures such as cardiac valve or thoracic surgery. There is a strong correlation between hyperglycemia and an increased risk of SSI.[14,155] Whether diabetes plays a role in increasing a patient's risk for an SSI is unclear; however, studies have shown that there is a correlation between increased levels of glycosylated hemoglobin and SSI rates.[14]

Preoperative antiseptic showers on the night prior to operation have been advocated to diminish colony counts of organisms on the skin, even though this has not definitively been shown to reduce surgical infection rates.[156] Skin preparation is a three-step process that involves the patient, the preoperative provider, and the surgical team. Skin preparation should begin at the patient's home as an outpatient or in a healthcare facility if a nonemergent inpatient procedure is scheduled. The three steps include a bath or shower with soap and water (with nursing assistance if necessary) within 24 hours of the procedure, application of a medicated antiseptic cleanser the day of procedure prior to going to surgery, and a surgical prep in the operating suite utilizing an approved antiseptic solution and aseptic technique.

In addition, the use of draping materials minimizes the risk of recolonization after skin prep is completed.[157,158]

Preoperative hair removal by shaving should be avoided.[159,160] If hair will interfere with the operation, removal just prior to the operation with electric clippers is preferred. *S. aureus* is one of the most common microorganisms found on the skin; it is also one of the most common pathogens associated with SSI. When a razor is used, small cuts and hair follicle disruption can occur; this creates a perfect environment for bacterial proliferation. Depending on how far in advance of the surgical incision time the surgical site was shaved, bacterial colonization of the patient's skin could increase greatly. Preparatory surgical shaving should be avoided if at all possible. If the attending surgeon requests that the hair be removed from the surgical site, it should be removed using electric clippers, and this process should take place as close as possible to the incision time. A good practice is to have the surgical site hair removed using either electric or battery-powered clippers in the preoperative holding area immediately before transporting the patient to the operating room.[161] An appropriate skin antiseptic agent should be used for skin preparation in the operating room and left to dry before draping the patient.[14]

Hypothermia may increase a patient's susceptibility to perioperative wound infections by causing vasoconstriction and impaired immunity. Vasoconstriction-induced tissue hypoxia may decrease the strength of the healing wound independently of its ability to reduce resistance to infection.[162]

Hypothermia is a threat for most surgical patients due to the surgical environment. The perioperative nurse can implement many simple measures to help reduce a patient's risk of hypothermia beginning in the holding area by taking measures to keep the patient warm, reducing the amount of time the patient is exposed during preparation of the surgical site, and positioning. The anesthetized surgical patient's core temperature should be monitored. Providing warm blankets both preoperatively and postoperatively, adjusting room temperatures to a comfortable level, and providing upper or lower body warming blankets or forced warm air (e.g., Bair-Hugger) intraoperatively will help patients maintain normothermia. Additional measures to help prevent heat loss include using warmed irrigation and infusing fluids throughout the perioperative period.

The appropriate use of perioperative antimicrobials, intravenously administered, is standard practice for surgical procedures involving implants.[14] The use of perioperative antimicrobials does not attempt to sterilize tissues but reduces the microbial burden of intraoperative contamination. The selection of agents should be based on efficacy against the most common pathogens expected to cause infection and other published recommendations. The timing of the initial dose should be such that a bactericidal concentration of the drug is established in serum and tissues by the time the skin is incised.[163]

Therapeutic levels of antimicrobials in both serum and tissues should be maintained throughout the operation until a few hours after the incision is closed in the operating room.[164]

Hand hygiene still remains a frontline strategy to minimize the transfer of bacteria into the operating room and to the patient. Orthopedic surgeons recommend the use of three sets of gloves, where the outer set is changed following draping. Gloves have a 33 percent contamination rate, half of which occur during the draping process. Because surgical gloves are a source of contamination, double gloving is a must during total joint arthroplasty to reduce perforation of the inner gloves. Changing gloves at regular intervals can decrease incidence of bacterial contamination. It is important to change gloves throughout a total joint procedure, especially if the surgical time extends beyond 3 hours or if an

obvious puncture in the gloves is seen.[165] Use of a different colored inner glove is an easy visual way to maximize the identification of a perforation.[166]

The operating room environment is crucial to minimize intraoperative contamination that can lead to infections in implanted devices. Efforts should be made to minimize personnel traffic during operations because the microbial level in the operating room is directly proportional to the number of people moving about in the room.[167,168] Two or more surgical residents participating in the operative procedure was an independent risk factor for infections in a study of orthopedic spinal operations.[169] Operating suites should be maintained at positive pressure with respect to adjacent rooms and corridors.[170] A minimum of 20 air exchanges per hour, of which at least four are fresh air, is recommended.[171] Air should be introduced at the ceiling and exhausted near the floor, as well as being filtered through the appropriate filters. Laminar airflow through high-efficiency particulate air (HEPA) filters has been shown to decrease orthopedic infections in patients with total knee and hip replacements.[172] However, this study also showed that antimicrobial prophylaxis is more beneficial than ultraclean air. A more recent retrospective cohort study of 63 surgical departments performing active SSI surveillance found the risk for severe SSI after hip prosthesis implantation was significantly *higher* using laminar HEPA airflow ventilation in the operating room as compared with turbulent HEPA ventilation, after controlling for many patient and hospital-based confounders. It also found no benefit to laminar air flow in the operating room for reducing infections after knee prosthesis surgeries.[173]

Compulsive sterile technique during the procedure, forethought regarding device placement, and hematoma prevention through pristine surgical technique, use of cautery, suture closure, pressure, and avoidance of low molecular weight heparin will reduce the opportunity for infection. Routine follow-up care with emphasis on teaching regarding early signs and symptoms of infection is important.

SCIP addresses four specific preventive factors that the healthcare professional has more definitive control in influencing. The project is focusing its attention on the control of hypothermia, the monitoring and correction of elevated blood glucose levels, the use of electric clippers to remove hair from the surgical site, and the administering of preoperative, procedure-specific antibiotics within an appropriate time frame.[174]

Prevention of infection in implanted medical devices is a combination of efforts from the entire surgical team, surgeon, medical physician, nursing staff, technicians, support staff, and the patient. The surgeon must have the surgical technique and skill to keep bleeding and tissue disruption to a minimum, and must direct others on the team to administer the correct prophylactic antibiotics on time and sustain a therapeutic dose range for long surgical cases.[175] The nurses must maintain the positioning and normothermia of the patient. The anesthesiologist must administer the antibiotics and monitor hemodynamics, and control blood glucose levels to promote optimum health. The entire healthcare team has a role in prevention. Particular attention should be paid to the cleanliness of the environment including the various pieces of equipment brought in and out of the surgical suite and the sterility of the instruments. Facility maintenance personnel must ensure the correct number of air exchanges, air temperature, air pressure differentials, humidity, and water quality to provide the best possible operating environment. The combined efforts of members of the healthcare team can ensure that best practices are followed to promote optimal surgical outcomes.[14]

Minimizing infections at the site of the closed incision and at remote sites after surgery is vital to maintain an uninfected device. Rapid healing of the skin incision without drainage or hematoma formation reduces the risk for deeper infection. Devices with endovascular implantation carry a risk of infection during episodes of bacteremia. *S. aureus*bacteremia in a patient with such a device prompts an immediate evaluation to see whether the device is infected. Efforts to minimize intravascular lines, when not required, will reduce this risk. The American Heart Association has recently updated antibiotic prophylaxis guidelines for high-risk patients receiving specific procedures.[176]These guidelines

recommend prophylaxis for those with prosthetic heart valves but not for those with cardiac pacemakers or defibrillators. Antibiotic prophylaxis is also not indicated for most dental patients with total joint replacements.[177]However, judgment is left to the clinician to prescribe antibiotic prophylaxis in certain

patients potentially at increased risk for hematogenous total joint infection. These include patients during their first year after joint replacements, immunocompromised patients, and others with defined comorbidities.

Conclusions

There are many considerations for the patients and providers for the insertion and maintenance of implanted medical devices. Multiple factors contribute to the success or failure of the implant. The selection of the materials of which the implants are made and how they may or may not contribute to biofilm resistance or the body's acceptance and integration are important considerations. The purpose and duration of the implant—if the implant is intended for temporary placement such as the LVAD or a permanent placement such as a total joint—are also important. The anatomical location of the implant, internal verses external, and the physical environment to include the location and conditions where the implant is inserted are factors to consider.

All these factors play an important role and are continually being researched. Based on current literature, strategies should be organized and implemented as stringent preoperative protocols. There are clinical practice bundles and checklists to assist in performing and achieving the best evidence-based practice. Ultimately, the success of a surgical procedure is dependent on vigilant sterile technique and aseptic environment, clean personnel and practices, and a healthy host.[178]These are foreign objects

and although intended to improve the patient's well-being, the body's natural defense mechanisms jump into action. The selection of the correct device, with forethought regarding placement; insertion under the sterile conditions, with the most pristine surgical technique for hematoma prevention; suture closure; and attentive postoperative care are necessary to have the optimum desired outcome.[14]

Future Trends

Researchers and clinicians all over the world are interested in exploring the numerous ways to prevent infections associated with implantable devices. The possibilities range from simple and basic practices such as hand hygiene, environmental cleanliness, and aseptic technique to elaborate investigations aimed at the materials implants are made of and how they interact with the natural defenses of the body at a cellular level to prevent biofilms. One approach being applied and investigated to prevent prosthetic device infection has been the coating of devices with antimicrobial substances. The anti-infective efficacy of silver-coated medical prostheses and the adhesives to hold them have recently been reviewed.[45]The assumption of this approach is that if colonization of the device could be prevented, so

could clinical infection. The use of antibiotic cement in total joint arthroplasty continues to provide evidence that new technological advances or different approaches may prove valuable in the prevention of prosthetic device infections.[45] Early animal models are envisioning a strategy using textured polyurethane to prevent infections, as seen in those with LVAD devices.[45]

As new devices and surgical techniques are considered, such as tunneling of LVAD drivelines,[179] and "no touch" or "minimal touch" techniques for breast implants,[180] so is the research to validate and continuously improve the surgical outcomes for the patient. The basic principles of personnel and environmental cleanliness, hand hygiene, and asepsis remain foundational elements to prevent infection in implanted devices.

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Pneumonia

Author(s): Paula Peyrani, MD

Assistant Director, Research Design and Development
Division of Infectious Diseases
University of Louisville
Louisville, Kentucky

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Abstract

This chapter describes the principal concepts regarding pneumonia and defines each type of pneumonia, epidemiology, pathogenesis, etiology, antimicrobial therapy, surveillance, and prevention measures.

Key Concepts

- Pneumonia remains the leading cause of death from infection in the hospitalized patient.
- Pneumonia is usually classified according to its site of origin (community-acquired, healthcare-associated). This delineation helps guide antimicrobial therapy decisions.
- Patients with pulmonary tuberculosis can present with a clinical picture of community-acquired pneumonia.
- Pneumonia surveillance and the evaluation of quality indicators are important tools to define areas for improvement.
- The creation of a local multidisciplinary team is important to develop and implement interventions to prevent development of pneumonia and to improve its management.

Background

Pneumonia is an inflammatory process of the lung parenchyma caused by a microbial agent. Microaspiration of oropharyngeal secretions is the most common route by which these microbial agents reach the lung. Once the microorganisms reach the lung and are able to kill the defense cells, the lung

develops a local inflammatory response, which then leads to a systemic inflammatory response. This inflammatory response, both local and systemic, is responsible for the majority of signs and symptoms and laboratory abnormalities seen in patients with pneumonia.[1]

Basic Principles

Pneumonia is often classified according to the site where symptoms are identified (e.g., community-acquired, healthcare-associated) because causative organisms are likely to be different and therefore treatment will likely differ. Pneumonia can also be further classified according to risk factors that may be directly associated with its development such as ventilator-associated pneumonia. For both clinical and surveillance purposes, it is essential to identify the place of onset and specific risk factors that are important for treatment and process improvement.

Based on the setting where pneumonia develops, it can be classified as follows:[2,3]

- **Community-acquired pneumonia (CAP):**Pneumonia occurring in any patient admitted to the hospital from the community.
- **Healthcare-associated pneumonia (HCAP):**A CAP occurring in patients with any of the following special epidemiological characteristics: (1) hospitalized in an acute care hospital for 2 or more days within 90 days of the current infection; (2) resided in a nursing home or long-term care facility; (3) received recent intravenous antibiotic therapy, chemotherapy, or wound care within the past 30 days of current infection; or (4) attended a hospital or hemodialysis clinic. These patients are considered to be at risk for colonization by bacteria similar to hospitalized patients and consequently are at risk for infection by potentially multidrug-resistant organisms (MDROs).
- **Hospital-acquired pneumonia (HAP):**Pneumonia developing ≥ 48 hours after admission to the hospital.
- **Ventilator-associated pneumonia (VAP):**HAP that develops in patients who have been intubated and have received mechanical ventilation for at least 48 hours.

BURDEN OF PNEUMONIA

Despite all the efforts over the last several years, the clinical and economic burden of CAP continues to be significant.[4]The incidence and hospitalization of adults with CAP are increasing and CAP remains as one of the top 10 causes of death. The annual direct cost for the treatment of CAP is over $17 billion; this is comparable to costs for chronic obstructive pulmonary disease, which is estimated to be between $10 and $26 billion.

Nosocomial pneumonia is the second most common nosocomial infection and has the highest mortality. VAP incidence is decreasing and this finding is thought to be related to several facts: prevention strategies such as the ventilator bundle, a new benchmark goal of "zero VAP," and classification of VAP as a "nonreimbursable event."[5]Hospital mortality of ventilated patients who develop VAP is 46 percent compared to 32 percent of those ventilated patients without VAP. VAP prolongs days on the ventilator, length of stay in the intensive care unit (ICU), and in the hospital. VAP also adds an estimated cost of $40,000 to a typical hospital admission.[6]

PNEUMONIA ETIOLOGY AND EMPIRIC THERAPY

Pneumonia may be caused by a large variety of microorganisms. Microbiological workup usually requires 1 to 3 days for culture and sensitivity; thus, the initial treatment for the majority of the patients is empirical. Empirical therapy is the initial regimen that is started when pneumonia is suspected and the pathogen is unknown. The American Thoracic Society (ATS) and the Infectious Diseases Society of America (IDSA) have developed national guidelines to help physicians with decisions on antibiotic selection.[2]

Etiology and Empiric Therapy for Community-acquired Pneumonia

The recommended empirical treatment for CAP should cover the four most common pathogens (*Streptococcus pneumoniae, Haemophilus influenzae*, *Moraxella catarrhalis,*and *Staphylococcus aureus*), as well as all the atypical pathogens (*Legionella*spp., C*hlamydia pneumoniae*, and *Mycoplasma pneumoniae*), and most of the relevant Enterobacteriaceae species. Based on epidemiological factors, national guidelines have the following recommendations:

Suspicion for *Pseudomonas aeruginosa*or methicillin-resistant *Staphylococcus aureus*(MRSA) as causative pathogens is the main reason to alter the suggested initial empirical therapy. Patients with CAP due to resistant organisms do not necessarily require ICU admission, so a high level of suspicion for these organisms needs to be maintained at all times.

Risk factors for infection with *Pseudomonas*species include structural lung disease (e.g., bronchiectasis), frequent or chronic steroid use, and prior antibiotic use.

Risk factors for *S. aureus*CAP include end-stage renal disease, injection drug abuse, prior influenza, and prior antibiotic therapy (especially with quinolones).

Community-acquired MRSA should be suspected in patients with severe CAP plus hemoptysis, multilobar or cavitary infiltrate seen on chest radiograph, or neutropenia.

Pulmonary tuberculosis (TB) caused by *Mycobacterium tuberculosis* can mimic CAP; therefore, TB should be suspected in all patients with a diagnosis of CAP who have risk factors for TB. The 25 risk factors for TB published by the Centers for Disease Control and Prevention (CDC) are provided in Table 36-1.[7]In patients with cough and pulmonary infiltrate, early diagnosis of CAP caused by *M. tuberculosis*is important for two reasons: to start treatment and to place the hospitalized patient into a special type of room with engineering controls (airborne infection isolation [AII]), thus decreasing the risk of transmission to others. See also **Chapter 95 Tuberculosis and Other Mycobacteria**.

Table 36-1 Risk Factors for Tuberculosis

Persons Who Have Been Recently Infected with TB Bacteria
• Close contacts of a person with infectious TB disease • Persons who have immigrated from areas of the world with high rates of TB • Children less than 5 years of age who have a positive TB test • Groups with high rates of TB transmission, such as homeless persons, injection drug users, and persons with HIV infection • Persons who work or reside with people who are at high risk for TB in facilities or institutions such as hospitals, homeless shelters, correctional facilities, nursing homes, and residential homes for those with HIV
Persons with Medical Conditions that Weaken the Immune System

- HIV infection (the virus that causes AIDS)
- Substance abuse
- Silicosis
- Diabetes mellitus
- Severe kidney disease
- Low body weight
- Organ transplants
- Head and neck cancer
- Medical treatments such as corticosteroids or organ transplant
- Specialized treatment for rheumatoid arthritis or Crohn's disease

Etiology and Empiric Therapy for HAP, HCAP, and VAP

HCAP, HAP, and VAP may be caused by a wide variety of pathogens but MDROs are becoming more relevant as etiologic agents. Risk factors for colonization and infection with multidrug-resistant pathogens are as follows:

- Antimicrobial therapy in preceding 90 days
- Current hospitalization of 5 days or more
- High frequency of antibiotic resistance in the community or in the specific hospital unit
- Presence of risk factors for HCAP (see Basic Principles section)
- Immunosuppressive state or therapy

Several risk factors can be evaluated to determine whether they are associated with the development of VAP or with VAP outcomes.

Risk factors that might be associated with the development of VAP include the following:

- Intubation type: Emergent versus nonemergent (emergent intubation may be associated with aspiration and development of VAP)
- Initial route of intubation: Orotracheal versus nasotracheal (nasotracheal intubation may be related with development of VAP)
- Etomidate use for intubation (etomidate has immunosuppressive action)
- Head of the bed not elevated
- Suboptimal oral care

Risk factors that might be associated with poor VAP outcomes include the following:

- Patient comorbidities
- Inappropriate prior use of antibiotics

PNEUMONIA SURVEILLANCE: QUALITY INDICATORS

There is no clinical definition of pneumonia that can identify with certainty a patient with pneumonia. Two sets of guidelines for pneumonia surveillance are available, the Joint Commission (TJC)/Centers for Medicare & Medicaid Services (CMS) standards for CAP, and the National Healthcare Safety Network (NHSN) definitions for healthcare-associated pneumonia.[8,9]

CAP and TJC/CMS

Quality assessment indicators for CAP that are founded on healthcare structures, processes, and outcomes have been recommended as potential audit tools to evaluate the delivery of care. The aim of these best practice indicators is to monitor and ultimately improve quality of care by organizations.[10]

The definition that TJC/CMS use to capture cases for the pneumonia national quality measures is not based on objective criteria. A case is defined by diagnosis of CAP at hospital discharge with physician documentation of the diagnosis of pneumonia written before or at admission. Pneumonia need not be the primary or only diagnosis, but mentioned as a working diagnosis at the time of admission.[8]

A summary of TJC/CMS national quality measures for CAP is as follows:[8]

- Blood cultures obtained within 24 hours (before or after) of arrival to the hospital
- Blood cultures performed in the emergency department before antibiotics were administered
- Antibiotic timing
- Antibiotic selection
- Pneumococcal vaccination
- Influenza vaccination
- Smoking cessation counseling

TJC objectives include the following:[8]

- Establishment of a national standardized data set from which routine and ad hoc customized data reports can be generated by accredited organizations
- Use of data to help identify and distinguish high reliability healthcare organizations
- Use of data to identify and disseminate evidence-based practices and to set national benchmarks
- Use of data to help determine healthcare organization–specific reimbursement levels (i.e., pay for performance)

Thus, these data could ultimately be used for accountability, payment, decision-making, accreditation, and quality improvement purposes.

NHSN and VAP

The NHSN pneumonia definitions were previously updated in 2002, and were designed to be used for surveillance of all HCAP events, including VAP.[11]These definitions were based on a combination of radiologic, clinical, and laboratory criteria. Some of these criteria were considered subjective, which made the VAP definition of limited use for public reporting or benchmarking.[12]

As of January 2013, a new definition is in place, proposing the surveillance of ventilator-associated events (VAE) for adults.[9]The data that are used to identify VAEs can potentially be automatically generated, allowing infection preventionists (IPs) to perform electronic surveillance. There are three definitions associated with the VAE algorithm: (1) ventilator-associated conditions, (2) infection-related ventilator-associated complication, and (3) possible and probable VAP. Not only acute care hospitals but also long-term acute care institutions and inpatient rehabilitation facilities are eligible to participate.

A detailed discussion of VAE criteria and algorithms is beyond the scope of this chapter. All this information, including training, flowcharts, forms, and VAE calculator can be found on the NSHN website.[13]

PNEUMONIA PREVENTION

Measures to Prevent CAP

Immunization and cessation of smoking can reduce the risk of CAP. The population of hospitalized patients with CAP should be considered a high-risk group for rehospitalization related to influenza or pneumonia.[1] ATS/IDSA national guidelines suggest that vaccination status should be assessed at the time of hospital admission for all patients. On admission, if patients are candidates, they should be vaccinated.[2] There is no contraindication for the use of the pneumococcal and influenza vaccine following an episode of CAP. Furthermore, these vaccines can be given simultaneously at different injection sites.[14]

Smoking is associated with increased risk of pneumococcal bacteremia and *Legionella* infection. Smoking cessation should be a goal for persons hospitalized with CAP who smoke.[1] Materials for clinicians and patients are available online from the U.S. Surgeon General (**http://www.surgeongeneral.gov/tobacco**), the CDC (**http://www.cdc.gov/tobacco**), and the American Cancer Society (**http://www.cancer.org**).

Measures to Prevent HAP, HCAP, and VAP

HAP, HCAP, and VAP are often considered events that could have been prevented if the quality of care had been optimal.[15] The principles for prevention are consistent across care settings from hospitals to long-term acute care facilities. Some of the several measures and processes are listed here and described further in this section:[15]

- Influenza and pneumococcal vaccination
- Hand hygiene
- Respiratory therapy equipment maintenance
- Avoidance of endotracheal intubation
- Selective oral decontamination
- Subglottic secretion drainage
- Isolation of patients with resistant organisms
- Reduction in the use of nasogastric tubes
- Start enteral feeding 24 to 48 hours after intubation
- Compliance with use of ventilator bundles

Data have been published on various measures that can be implemented with the objective of preventing the development of HAP, HCAP, and in particular VAP.[15,16,17] Following is a brief description of some of the suggested actions for preventing VAP.

Staff Education and Involvement in Infection Prevention

Prevention of VAP requires close collaboration among pulmonary and critical care specialists, infectious disease practitioners, IPs, radiologists, clinical pharmacists, and microbiologists.

Education of healthcare personnel (HCP) regarding VAP and infection prevention is very important. Because colonization with hospital bacteria can be initiated with the transfer of bacteria from HCP, simple yet effective prevention measures, including hand hygiene and appropriate use of barriers (gloves and gown use) and standard precautions, should be emphasized. Immunizations (e.g., measles-mumps-rubella, pertussis, influenza) for HCP are recommended.[16] Influenza outbreaks in hospitals and long-term care facilities have been associated with low vaccination rates among HCP. The Advisory Committee on Immunization Practices (ACIP) recommends that HCP be vaccinated against influenza.[18]

Improving acceptance of influenza immunization among HCP is a targeted intervention by TJC and is also a statutory requirement in some states. CMS requires acute care hospitals to report HCP influenza vaccine as part of its hospital inpatient quality reporting program.[17] See also **http://www.cancer.org**.

Prevention of Person-to-Person Transmission of Bacteria

The following guidelines should be practiced in hand hygiene and gloving procedures:

- Hand hygiene
  - Perform hand hygiene after contact with mucous membranes, respiratory secretions, or objects contaminated with respiratory secretions whether or not gloves are worn. Use soap and water if hands are visibly dirty or contaminated with body fluids. Use alcohol-based waterless antiseptic agents if hands are not visibly soiled.
  - Perform hand hygiene before and after contact with a patient who has an endotracheal or tracheostomy tube in place. Decontaminate hands as described previously.
- Gloving
  - Wear gloves for handling respiratory secretions.
- Change gloves and perform hand hygiene as previously described between contacts with different patients and when moving between clean and dirty tasks on the same patient.

Infection and Microbiological Surveillance

Surveillance cultures, in particular in the ICU, should be performed only with the goal of defining trends and helping identify outbreaks and other potential infection prevention and control problems. Do not perform routine surveillance cultures if no specific clinical, epidemiological, or infection prevention objective has been determined.

Respiratory Care Equipment

The following practices are necessary in prevention of microorganism transmission:

- Ventilator circuits should not be changed routinely. Change the breathing circuit when it is visibly soiled or mechanically malfunctioning.
- Periodically drain and discard any condensate that collects in the tubing of a mechanical ventilator.
- Use sterile water to fill bubbling humidifiers.
- No clear recommendation is available regarding use of heat-and-moisture exchangers or heated humidifiers.

- Respiratory filters should not be used routinely. Use filters in patients with suspected or confirmed pulmonary TB.

Precautions for Prevention of Aspiration

The following precautions should be practiced for prevention of aspiration:

- Use of noninvasive ventilation, when possible, to reduce the need for and duration of endotracheal intubation. This refers to all modalities that assist ventilation without the use of an endotracheal tube.
- Perform orotracheal intubation unless contraindicated. Nasotracheal intubation has been associated with higher incidence of nosocomial sinusitis, making the patient more prone to development of pneumonia through aspiration of infected secretions.
- The head of the bed should be elevated at an angle of 30 to 45 degrees.
- Oropharyngeal cleaning and decontamination should be performed with an aseptic agent (e.g., chlorhexidine).
- Stress ulcer prophylaxis may be provided with proton-pump inhibitors, histamine-2 receptor antagonist, or sucralfate.

VAP Prevention Bundle

Elements of a VAP bundle that have been suggested by the Institute for Healthcare Improvement include the following:[6]

- Elevation of the head of the bed
- Daily "sedation vacations" and assessment of readiness to extubate
- Peptic ulcer disease prophylaxis
- Deep venous thrombosis prophylaxis
- Daily oral care with chlorhexidine

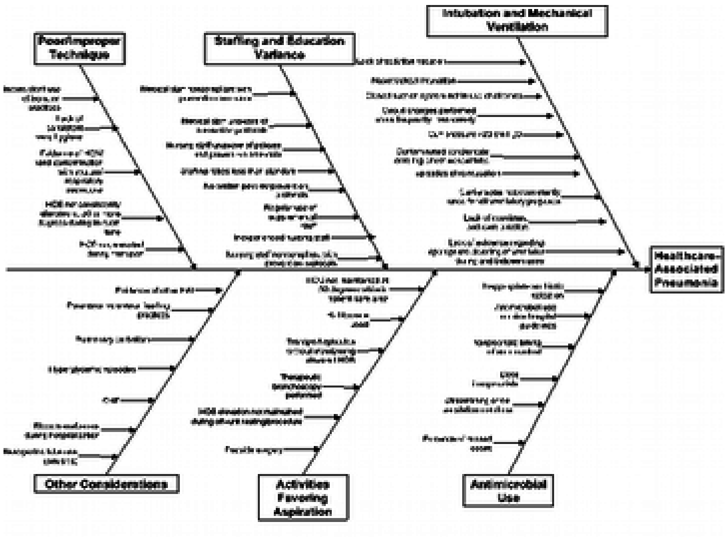
Oral immunity is reduced after intubation leading to accumulation of dental plaques, which may then be colonized by oral microorganisms. Published data suggest a link between plaque colonization and development of VAP.[19]Oral care as a means of reducing oral flora that may be aspirated has become an intriguing additional element for this prevention bundle.[19]Oral hygiene care includes the use of mouth rinses, removal of excessive oral fluid by periodic suctioning, and antiseptics.

VAP Fishbone Diagram

When an unanticipated death or serious injury occurs (such as VAP), regardless of the reason, the hospital is expected to conduct a thorough and credible root cause analysis, determine areas of risk and whether the risk can be reduced, implement improvements to reduce risk, and monitor the effectiveness of those improvements. Once a patient develops VAP, it may be identified as a sentinel event and a root cause analysis can be performed as a means of identifying deviations from best prevention practice. A sample fishbone diagram for sentinel event analysis involving VAP has been provided in Figure 36-1.[20]

This fishbone is the compilation of work among IPs from a variety of healthcare settings over the course of several years.

Figure 36-1.



Fishbone diagram for sentinel event analysis involving healthcare–associated

View Image

The skeleton of the fishbone diagram includes six elements associated with the possibility of having increased risk for developing VAP. Each of these elements has subitems with a more direct relationship with the development of VAP, as follows:

- Intubation and mechanical ventilation
- Staffing and education variance
- Poor/improper technique
- Antimicrobial use
- Activities favoring aspiration
- Other considerations

Conclusions

Pneumonia represents significant morbidity and mortality risks to the patient, increased healthcare costs, and potential risk to HCP. Identifying the most likely etiology of the pneumonia, targeting and streamlining antimicrobial therapy, developing and implementing strategies to prevent development of pneumonia, ensuring the safety of other patients, and HCP through immunization and environmental controls are all components of an effective infection prevention and control program. Many of these elements are included in existing and forthcoming quality initiatives. Understanding that patient outcomes are becoming part of public reporting may serve as a motivator for improving both medical care and healthcare processes.

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Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Surgical Site Infection

Author(s): Donald E. Fry, MD
Adjunct Professor of Surgery

Northwestern University
Feinberg School of Medicine
Chicago, IL

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Declarations of Conflicts of Interest: Donald Fry serves on the Board of the Surgical Infection Foundation and is a past president of the organization. He is currently a member of 25 surgical societies and holds no offices for any of these societies at the time of publication. He speaks periodically on surgical infections for Merck and has been a consultant and speaker for Ethicon on two occasions within the last year. At the time of publication, Dr. Fry was organizing a controlled clinical trial for the IrrIMax Company on the use of an innovative application of dilute chlorhexidine in the surgical wound.

Abstract

Surgical site infection continues to be a major source of morbidity, economic cost, and even deaths in surgical patients. They occur as part of a complex interaction between the number of bacteria that contaminate the surgical site, the virulence of the contaminant, the microenvironment at the surgical site, and the integrity of host defense. Different surgical sites from different types of operations are at different risks for infection. Of importance, acute and chronic medical conditions become important variables in modulating the effectiveness of the host response, and hence the likelihood that infection will occur. The actual rates of surgical site infection for most operations remain poorly defined because many procedures are performed on an outpatient basis, many infections in the inpatient population are not identified until after discharge, and the thoroughness of surveillance remains inconsistent. Multiple preventive measures, including the judicious use of preoperative antibiotics, have been demonstrated to reduce the frequency of surgical site infections. Even with the use of all of the effective preventive measures, infections still occur and require effective management to minimize the consequences of the infection.

Key Concepts

- Essentially every surgical site is contaminated with bacteria by the end of the procedure, but only a minority of sites gets infected.
- The probability of infection is determined by the interaction of four clinical variables: (1) inoculum of bacteria, (2) virulence of bacteria, (3) adjuvants in the microenvironment, and (4) efficiency of host defenses.
- Surveillance of surgical site infections historically was focused on the identification of events during the patient's hospitalization. With shorter days of inpatient care and with increased numbers of ambulatory procedures, surveillance has been extended beyond the period of hospitalization. By capturing all infections and defining rates of occurrence, the healthcare personnel and the healthcare facility can monitor changes in rates, and implement improvements in preventive strategies.
- Prevention of surgical site infections follows the principles of managing those events associated with causing infection. Thus, prevention consists of minimizing access of bacteria to the surgical site, neutralizing those bacterial species that do gain access to the wound, reducing adjuvant effects that create a local environment conducive to infection, and optimizing host immune responses to potential pathogens.
- The foundational principles in the management of the infected surgical site are: (1) open and drain the incision, (2) debride fibrinous debris and necrotic soft tissue, (3) remove foreign bodies, (4) implement antimicrobial management as needed, and (5) manage the open wound.

Background

Surgical site infections (SSIs) have been a consistently identified complication of surgical care. The introduction of hand washing by Semmelweis into obstetrical care in the 1840s and the evolution of the germ theory of disease by Pasteur and Koch in the 1860s led to the classic studies of Joseph Lister in the use of antiseptics in the prevention of SSIs in the 1870s. The introduction of antiseptics was a forerunner to the development of operating rooms in the early 1900s. In the operating room environment, a code of infection prevention and control practices was developed that included surgical gloves and protective barriers to further prevent bacteria from gaining access to the open surgical wound. The development of antibiotics was another great advancement in the prevention of SSIs, although their proper role in the prevention of SSIs was not appreciated until foundation studies were done in the 1960s.

There are many millions of inpatient and ambulatory surgical procedures performed each year in the United States (US), and that number has been steadily increasing. SSIs account for 25 percent of all healthcare-associated infections (HAIs) and now are identified as the most common HAIs.[1] SSIs are responsible for extended lengths of postoperative hospital stay and thousands of dollars in excess costs per patient.[2]

SSIs occur as a result of a complex interaction between the microbial contamination of the surgical site, the local environment at the site of contamination, and the efficiency of the host response. Although it is theoretically appropriate to consider all SSIs to be potentially preventable, experienced surgeons know that the complexity of the multiple interactions of microbe and host will result in infections in even the most skilled of surgical hands. Nevertheless, it is certainly true that the application of evidence-based preventive measures can reduce overall infection rates by a substantial degree. This chapter focuses on

these multiple interactions and discusses the accepted methods that should be employed in the prevention of infection. It also addresses important issues in surveillance methods and the role public reporting of SSIs. Finally, management of SSIs is briefly discussed.

Basic Principles

PATHOGENESIS OF SURGICAL SITE INFECTIONS

Essentially every surgical site is contaminated with bacteria by the end of the procedure. Quantitative cultures will document bacteria from the subcutaneous tissues in virtually every case, but only a minority of surgical sites becomes clinically infected. The source of the pathogen for SSIs may be the air of the operating room, or surgical instruments, or breaches in the surgeons' gloves. Contamination commonly arises from endogenous microflora of the patient's skin. Operations that violate areas of normal colonization such as the oropharyngeal cavity or the gastrointestinal tract will result in these endogenous bacteria contaminating the site. The probability of infection is determined by the interaction of four clinical variables: (1) inoculum of bacteria, (2) virulence of bacteria, (3) adjuvant effects in the microenvironment of the wound that enhance microbial virulence, and (4) efficiency of host defenses.

Inoculum of Bacteria: Wound Contamination

The risk for SSI is related to the number of microorganisms contaminating the wound. For each microbial species a quantitative threshold can be identified at which excessive contamination results in infection. That has commonly been identified as 10^5bacteria per gram of tissue, but this threshold is unique for each microbe. The largest inoculum of bacteria that gain access to the surgical site occurs when the operation invades a body structure that is ordinarily heavily colonized with bacteria, such as the intestinal tract, female genitourinary tract, or respiratory tract. Most notably, the human rectosigmoid colon may have bacterial density of 10^{12}bacteria per gram of mucosal tissue, which means that any procedure that enters into the colon lumen will result in major microbial contamination of the surgical site.[3]

Virulence: Microorganism-related Risk Factors

A second variable that contributes to the risk for SSI is the virulence of the bacterial contaminant. The more virulent the microorganism, the lesser the inoculum of contamination that is required at the surgical site and the greater the probability of infection. Coagulase-positive staphylococci (*Staphylococcus aureus*), group A streptococci (*Streptococcus pyogenes*), and *Clostridium perfringens*require only a small inoculum to cause severe and necrotizing infections at the surgical site. Some bacteria such as *Escherichia coli*have endotoxin as a component of the cell structure, which can cause severe local and systemic inflammatory effects. Other bacteria release exotoxins that can directly damage tissue or inhibit host defenses, of which the Panton-Valentine leukocidin that is produced by community-associated methicillin-resistant *S. aureus*(MRSA) is an example.[4]An additional microbe-related factor is the possibility for microbial synergism. This is demonstrated by the enteric anaerobe *Bacteroides fragilis*, which has relatively low virulence in experimental models when used alone to cause infection, but when part of a polymicrobial infection that includes facultative Gram-negative bacteria, can cause severe infections.[5]

Adjuvant Effects of the Microenvironment

A third important variable for infection at the surgical site is the microenvironment of the surgical wound. The local environment of a surgical wound can predispose to infection in several ways, each of which has the net effect of requiring fewer contaminating microbes to cause infection. Hemoglobin at the surgical site in the form of a hematoma stimulates microbial proliferation by providing ferric iron with the degradation of red blood cells, potentially leading to infection. Foreign bodies such as surgical sutures or implanted surgical devices provide a surface for microbial proliferation that is not readily managed by phagocytic defenses. The presence of necrotic tissue is thought to provide a sanctuary for contaminants to also avoid phagocytic actions of the host. Surgical wounds with large dead space result in the accumulation of serum and other inflammatory fluids that similarly pose an obstacle for the phagocytosis of contaminants by leukocytes. Thus, meticulous surgical technique to avoid these local events is critical to the prevention of infection.

Impaired Host Defenses

Finally, it has been appreciated for decades that different patients when exposed to similar bacterial inocula with similar virulence characteristics may have different rates of SSI because of the efficiency of host defense. Genetic variability certainly exists, with some patients having an intrinsically more efficient host response than others.[6] However, it is more likely that acute and chronic abnormalities of the host create acquired impairment of host defenses. Many patient-related factors have been evaluated in an attempt to determine those patients who might have risks likely to cause postoperative infectious complications. Morbid obesity, extremes of age, prolonged preoperative hospital stay, infection at other sites, low albumin, cancer, poor vascular supply in the wound, neutropenia, diabetes mellitus, nicotine use, steroid use, preoperative nasal colonization with *S. aureus*, perioperative transfusion, immunosuppressive therapy, and other variables have all been implicated in increasing the risk of surgical site infection.[7]

CLASSIFICATION OF AND RISK FOR SURGICAL SITE INFECTION

Surgical procedures have varying probability of infection depending on the four clinical variables outlined earlier. For example, cosmetic operations of the head and neck in someone who is otherwise healthy have a much lower risk for SSI than colon resection in an elderly patient with diabetes and obesity. Elective procedures carry a lower risk for postoperative infection than urgent ones. It is important to consider these factors when making decisions regarding surgical outcomes and quality improvement assessments.

The traditional wound classification system of categorizing procedures into risk groups based on the degree of microbial contamination has been available since 1964 and for many years was used as the sole determinant of surgical risk.[8] This method of wound classification has been adopted by the American College of Surgeons (ACS) and has been effectively used for more than 40 years to stratify patients by risk for SSI. It has the shortcoming that it uses only the inoculum of bacterial contamination expected during a procedure as the principal variable for predicting infection and host factors are not considered. The four classes of wounds in this classification model are as follows:

- *Class I, or clean wounds*, are those in which no inflammation was encountered. No contaminated spaces (gastrointestinal, respiratory, genitourinary, and genital) were encountered, and the wound was primarily closed and drained if necessary with closed drains.
- *Class II, or clean-contaminated wounds*, are those in which the respiratory, urinary, gastrointestinal, or genital tracts were entered under controlled conditions and without unusual contamination. A minor break in surgical sterile technique in an otherwise class I procedure would also fit into this class.

- *Class III, or contaminated wounds*, are those with gross spillage from the gastrointestinal tract. Entry into the genitourinary or biliary tracts in the presence of infected urine or bile or a major break in surgical technique may have occurred. Incisions in which acute, nonpurulent inflammation was present are also included in this class.
- *Class IV, or dirty and infected wounds*, are those with retained devitalized tissue, foreign bodies, fecal contamination, or delayed treatment or from a dirty source. A perforated viscus may have been encountered. A wound with acute bacterial inflammation with pus encountered during the operation is also included in this class.

However, there was clearly a need for a prediction model that included more than just the projected estimate of bacterial contamination. In 1985, a new model was developed to stratify SSI risk.[9] This model was based on a logistic regression model of 10 variables collected in the Study of the Efficacy of Nosocomial Infection Control (SENIC) project. This study showed that four variables are independently associated with SSI risk: (1) abdominal operation, (2) operation lasting more than 2 hours, (3) surgical site with wound classification of either contaminated or dirty/infected, and (4) patient with more than two discharge diagnoses. Taking these factors into consideration allows risk stratification of operations so that surveillance outcome data are more meaningful.

The results of the SENIC project were further modified by the Centers for Disease Control and Prevention (CDC) with the development of the National Nosocomial Infection Surveillance (NNIS) Risk Index in 1991.[10] NNIS has now transitioned to the National Healthcare Safety Network (NHSN), but the risk index methodology remains the same. This simplified risk index has a range from 0 to 3 points. A point is added to the patient's risk index for each of the following three variables:

- Surgical site wound classification of contaminated or dirty (class III or IV)
- American Society of Anesthesiology (ASA) score as rated by an anesthesiologist before operation of ≥3 (Table 37-1)[11]
- Prolonged procedure time, where the threshold in minutes (i.e., the cut point) is above the 75th percentile of the duration of surgery for the specific procedure being performed as determined by the NHSN database.

Table 37-1 Descriptor of the Six Categories That Currently Comprise the American Society of Anesthesiology Physical Status Classification System*

ASA Score	Description of Classification	Patient Example
1	Normal healthy patient	A 21-year-old, well-conditioned male athlete undergoing elective groin hernia repair
2	Patient with mild systemic disease	A 46-year-old woman with mild but controlled hypertension undergoing a laparoscopic cholecystectomy
3	Patient with severe systemic disease	A 53-year-old man with insulin-dependent diabetes and coronary artery disease undergoing elective aortofemoral bypass
4	Patient with severe systemic disease that is a constant threat to life	A 62-year-old woman on chronic renal hemodialysis undergoing emergency laparotomy for perforative diverticulitis

5	Moribund patient who is not expected to survive without the operation	A 58-year-old man with morbid obesity, type 2 diabetes, and shock undergoing extensive debridement for streptococcal necrotizing fasciitis
6	Patient declared brain-dead whose organs are being removed for donor purposes	A 35-year-old male motorcycle accident victim with brain death and normal cardiac function, for multiorgan thoracic and abdominal organ donation

*These classes are clearly subjectively determined but have been very accurate in the prediction of risk of surgical site infection when applied by experienced anesthesiologists.
Source: American Society of Anesthesiologists (ASA). ASA physical status classification system. ASA website. 2013. Available at: **http://www.asahq.org/clinical/physicalstatus.htm**.

The higher the score by this index, the greater is the risk for subsequent SSI. Thus, this index takes into account the microbial burden, length of surgery as a surrogate marker for surgical complexity, and patient-specific factors. The ASA score allows anesthesiologists to preoperatively assess the overall physical status of a patient. The NHSN Risk Index has become a standard format for presenting SSI data. An accurate profile of infection outcomes can then be evaluated against risk, as is seen in Table 37-2.[12] The rates of SSI show progressive increases as the number of NHSN risk index points increase.

Table 37-2 Rates of Surgical Site Infection and National Healthcare Safety Network (NHSN) Risk Index for Six Commonly Performed Operations*

Procedure	Cut Point (minutes)	NHSN Risk Index			
		0 (%)	1 (%)	2 (%)	3 (%)
Colon resection	187	3.99	5.59	7.06	9.47
Coronary artery bypass with donor incision	301	0.35	2.55	4.26	8.49
Spinal fusion	239	0.70	1.84	4.15†	—
Herniorrhaphy	124	0.74	2.42	5.25†	—
Hip prosthesis	120	0.67	1.44	2.40†	—
Abdominal hysterectomy	143	1.1	2.2	4.05†	—

*The cut point is identified in minutes. Procedures that exceed the cut point in duration have one risk point added to the NHSN risk index. †Indicates that risk index groups 2 and 3 have been pooled together because of small total cases.
Source: Edwards JR, Peterson KD, Mu Y, et al. National Healthcare Safety Network (NHSN) report: data summary for 2006 through 2008, issued December 2009. *Am J Infect Control* 2009;37:783-805.

DEFINITIONS AND SURVEILLANCE OF SURGICAL SITE INFECTION

The CDC has provided standardized definitions for SSI.[13] The original definitions of superficial, deep, and organ/space SSI were an effort to standardized reporting so that rates from the nationally participating

hospitals could be used as a benchmark for individual hospitals to measure their own performance. Furthermore, the three categories of SSI allow stratification of infection events by severity. In general, superficial SSI is an infection that involves the skin and subcutaneous tissue of the surgical wound (Table 37-3). It may be in the primary surgical incision or in the secondary surgical incision. Superficial SSIs can be quite innocent in terms of clinical morbidity, but can be quite morbid when infection extends down to the level of the investing fascia of the underlying muscle. The surveillance period to identify a superficial incisional SSI is 30 days for all procedure types.

Table 37-3 Definition of Superficial Incisional Surgical Site Infection (SSI) by the National Healthcare Safety Network (NHSN)

Infection occurs within 30 days after any NHSN operative procedure, infection involves only skin or subcutaneous tissue of the incision, and the patient has at least one of the following:

1. Purulent drainage, with or without laboratory confirmation, from the superficial incision.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision.
3. Superficial incision is deliberately opened by a surgeon and is culture-positive or not cultured, and patient has at least one of the following signs or symptoms: pain or tenderness; localized swelling; redness; or heat. A culture-negative finding does not meet this criterion.
4. Diagnosis of superficial incisional SSI by the surgeon or attending physician, or other designee (nurse practitioner or physician's assistant).

Comments and Reporting Instructions:

1. There are two specific types of superficial incisional SSIs:
   - Superficial Incisional Primary: a superficial incisional SSI that is identified in the primary incision in a patient that has had an operation with one or more incisions (e.g., median sternotomy incision for coronary artery bypass grafting).
   - Superficial Incisional Secondary: a superficial incisional SSI in a secondary incision (e.g., donor site in a coronary artery bypass grafting).
2. Do not report stitch abscess (minimal inflammation and discharge confined to the points of suture penetration).
3. Do not report a localized stab wound or pin site infection as an SSI.
4. Do not report cellulitis by itself as an SSI.
5. Incisional SSI that extends into the fascial and muscle layers is reported as a deep incisional SSI, not a superficial SSI.
6. Do not report circumcision infection as an operative superficial SSI.
7. Burn wound infections are reported elsewhere and not as a superficial SSI.

Source: Centers for Disease Control and Prevention (CDC). July 2013 CDC/NHSN Protocol Clarifications. CDC website. 2013. Available at: **http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf**.

The deep incisional SSI is defined in detail in Table 37-4. Infection involves the underlying fascia and muscle. These infections may extend into the subcutaneous and skin tissues, but are classified as deep incisional SSI. These infections also are separated into those that are in the primary incision and those that are in the secondary incisions. Deep incisional SSIs will have different periods for surveillance since infection may not be clinically discernible until a later time interval for selected operations. Table 37-5 identifies the operations that are subject to 30 days versus those that are subject to 90 days of surveillance. Selected operations especially when prosthetic materials are employed may actually have an infection not declared until a much later date, but the standard time intervals provide a fixed reference period for active clinical surveillance.

Table 37-4 Definition of Deep Incision Surgical Site Infection (SSI) by the National Healthcare Safety Network (NHSN)

Infection occurs within 30 or 90 days after the NHSN operative procedure (Table 37-5) *and*involves deep soft tissues of the incision (e.g., fascial and muscle layers), *and*the patient has one of the following:

- Purulent drainage from the deep incision (i.e., pus)
- A deep incision that spontaneously dehisces or is deliberately opened by a surgeon and is culture-positive or not cultured, *and*the patient has at least one of the following signs and symptoms: fever (>38ºC); localized pain or tenderness. A culture-negative finding does not meet this criterion.
- An abscess or other evidence of infection involving the deep incision that is found on direct examination, during invasive procedure, or by histopathologic examination or imaging test.
- Diagnosis of a deep incisional SSI by a surgeon or attending physician or other designee (nurse practitioner or physician's assistant).

Comments and Reporting Instructions:

- There are two types of deep incisional SSIs:
  - Deep Incisional Primary: a deep incisional SSI that is identified in a primary incision where multiple incisions may exist (e.g., median sternotomy incision in a coronary artery bypass grafting).
  - Deep Incisional Secondary: a deep incisional SSI that is identified in the secondary incision where multiple incisions may exist (e.g., donor site incision in a coronary artery bypass grafting).
- Infections involving both superficial and deep sites should be classified as deep incisional SSIs.
- Infections involving superficial incisional, deep incisional, and organ/space sites should be classified as deep incisional.
- The attending physician is interpreted to mean:
  - Surgeon
  - Infectious disease specialist
  - Other physician on the case
  - Emergency physician
  - Physician's designee

Source: Centers for Disease Control and Prevention (CDC). July 2013 CDC/NHSN Protocol Clarifications. CDC website. 2013. Available at: **http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf**.

Table 37-5 Surveillance Periods for Deep Incision or Organ/Space Surgical Site Infection by Procedure as Recommended by the National Healthcare Safety Network

30-day Surveillance	90-day Surveillance
Abdominal aortic aneurysm repair	Breast surgery
Limb amputation	Cardiac and coronary artery surgery
Appendectomy	Craniotomy
Shunt for dialysis	Spinal fusion or refusion
Gastric/bile duct/liver/pancreatic surgery	Open reduction of fractures
Carotid endarterectomy	Herniorrhaphy
Colorectal and small bowel surgery	Hip or knee prosthesis
Cesarean section, abdominal or vaginal hysterectomy, ovarian surgery	Pacemaker procedure

Heart/kidney/liver transplantation	Peripheral vascular surgery
Laminectomy	Ventricular shunt
Thyroid/parathyroid/neck surgery	
Kidney or prostatic surgery	
Spleen surgery	
Non-cardiac thoracic surgery	
Exploratory laparotomy	

Source: Centers for Disease Control and Prevention (CDC). July 2013 CDC/NHSN Protocol Clarifications. CDC website. 2013. Available at: **http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf**.

The organ/space SSI is defined in Table 37-6. This is a far more heterogeneous group of infectious complications and is the group that has the highest morbidity and mortality consequences. These are characteristically deeply seated infections within visceral cavities or in structural components of the patient. These sites of infection are detailed in Table 37-7. Examples are abdominal abscess following laparotomy, empyema of the pleural space following thoracotomy, and prosthetic hip or knee infections following joint replacement. Surveillance for specific operations should be compliant with procedural stratification identified in Table 37-5.

Table 37-6 Definition of Organ/Space Surgical Site Infection (SSI) as Recommended by the National Healthcare Safety Network (NHSN)

Infection occurs within 30 or 90 days after the NHSN operative procedure (Table 37-5) *and*infection involves any part of the body, excluding the skin incision, fascia, or muscle layers, that is opened or manipulated during the operative procedure, *and*meets at least one of the criteria for an organ/space infection site listed in Table 37-7, *and*the patient has at least one of the following:

- Purulent drainage from a drain that is placed into the organ/space.
- Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ space.
- An abscess or other evidence of infection involving the organ/space that is found on direct examination, during invasive procedure, or by histopathologic examination or imaging test.
- Diagnosis of an organ/space SSI by a surgeon or attending physician or other designee (nurse practitioner or physician assistant).

Comments and Reporting Instructions:

- Because an organ/space SSI involves any part of the body (excluding skin incision, fascia, or muscle layers) that is manipulated during the operative procedure, criteria for infection at these body sites must be met in addition to the organ/space SSI criteria. Table 37-7 lists the specific sites that must be used to differentiate organ/space SSI.
- If a patient has an infection in the organ/space being operated on and the surgical incision was closed primarily, subsequent continuation of this infection type during the remainder of the surveillance period is considered an organ/space SSI, if organ/space SSI and site-specific infection criteria are met.
- Occasionally an organ/space infection drains through the incision and is considered a complication of the incision. Therefore, classify it as a deep incisional SSI.
- Report mediastinitis after cardiac surgery as a mediastinal-SSI not a bone-SSI.
- If meningitis and a brain abscess are present together after operation, report it as intracranial infection.
- Report CSF shunt infection as meningitis SSI if it occurs within 90 days of placement; if later or after manipulation/access, it is not reported as an SSI.
- Report spinal abscess with meningitis as meningitis SSI following spinal surgery.
- The attending physician is interpreted to mean the surgeon(s), infectious disease, other physician on the case, emergency physician, or physician's designee.

Source: Centers for Disease Control and Prevention (CDC). July 2013 CDC/NHSN Protocol Clarifications. CDC website. 2013. Available at: **http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf**.

Table 37-7 Specific Sites of Organ/Space Surgical Site Infection as Defined by the National Healthcare Safety Network

Osteomyelitis
Breast abscess or mastitis
Myocarditis or pericarditis
Disc space
Ear/mastoid
Endometritis
Endocarditis
Eye (not conjunctiva)
GI tract
Hepatitis
Intraabdominal (not otherwise specified)
Intracranial, brain abscess, dura
Joint or bursa
Other respiratory tract infections
Mediastinitis
Meningitis or ventriculitis
Oral cavity
Other male or female reproductive tract infections
Other urinary tract infections
Spinal abscess without meningitis
Sinusitis
Upper respiratory tract infection
Arterial or venous infection
Vaginal cuff infection

Source: Centers for Disease Control and Prevention (CDC). July 2013 CDC/NHSN Protocol Clarifications. CDC website. 2013. Available at: **http://www.cdc.gov/nhsn/PDFs/pscManual/9pscSSIcurrent.pdf**.

Surveillance of SSIs remains an important monitoring process for all surgical patients. Surveillance historically has been considered an important process that was focused on the identification of events during the patient's hospitalization. However, shorter lengths-of-stay following inpatient procedures mean that the majority of SSIs may not be identified until following discharge. Shorter lengths of stay means that follow-up ambulatory records, microbiological reports, and programs where patients are contacted directly by mail or phone to discuss the outcomes at the surgical site are important. Readmissions for SSIs may actually not occur at the hospital where the index procedure was performed, and may require

(the unthinkable) that hospitals share information about readmissions not originating from their own institution.

Another complex situation is the surveillance for SSIs following ambulatory surgery. More than 50 percent of operations in the United States are performed in an ambulatory environment with the patient going home immediately following the procedure. Some infections can be captured by self-reported events by the surgeon, but this is not likely to be comprehensive. Follow-up for postsurgical care will occur in private physician offices and the ambulatory surgical center (ASC) will not have access to records necessary to define whether SSI has occurred. Direct patient contact by mail or phone remains currently the most important method for determining whether SSI has occurred. This means that free-standing ASCs that are not aligned with hospital infection prevention and control programs will need infection preventionists (IPs) to coordinate implementation of policies and direct surveillance efforts.

By capturing infections and monitoring changes in rates of these adverse events over time, the clinician, the IP, and the hospital can assess the impact of preventive measures and identify whether processes of care need reevaluation or modification. The observed rates of infection are usually stratified by either the NHSN risk index or by the ACS wound classification method for internal evaluation.

Recently, the analysis of hospital-specific SSI rates has been proposed by using the standardized infection ratio (SIR). SIR is tabulated by dividing the observed SSI rate within a hospital by the expected rate. It must be emphasized that only NHSN data should be used, since the SSI rates for very high risk cases such as acute trauma and emergency procedures will fall outside of these comparative parameters. The expected rate is calculated by probabilities derived by multivariate logistic regression models.[14] A SIR ratio greater than 1.0 indicates SSI rates that exceed the expected rates identified in the risk-adjusted model population. Guides on using NHSN analysis features are available.[15] See also **15. Risk-Adjusted Comparisons**.

Words of caution are appropriate when interpreting a given hospital's SSI rates compared against national data, even with NHSN risk stratification. First, the national trend to less invasive procedures will make true current infection rates less than historical controls. Second, reported infection rates will commonly reflect those events identified during the course of inpatient care and likely underreport true overall SSI rates of postdischarge infections. Third, effective and diligent infection surveillance that reports all SSIs during the total inpatient and postdischarge period of time will also generate far more events than might be reported from publicly available benchmarks. The result will make the hospital appear less effective. Public reporting of outcomes data will make rigorous surveillance a potentially damaging enterprise without a standardized process across the country. Standards for the surveillance and reporting of SSIs are being pursued by NHSN, but the problems of postdischarge surveillance remain. When a hospital has an effective and standardized surveillance program, *the best utilization of the data is to compare risk-adjusted outcomes internally over time, and to implement improved processes to change outcomes.*

It would be a significant advancement if the reporting of SSIs could be done by the identification of both the severity of the infection and the risk of the operation. In Table 37-8, the NHSN classification of risk is combined with the severity of infection to provide a true overview of the range of infections that can occur. An R S_3event is a clinical misadventure that requires intensive evaluation and analysis, while an R_3S_1might more appropriately be viewed as a clinical success rather than a reportable adverse event. An issue that must be addressed for the future is tracking of events following discharge so that a valid appraisal of SSIs can be made. It is very difficult to implement improvement strategies when the true rate of SSIs is unknown. It is certainly higher than NHSN or other publicly reported rates. This again

underscores why surveillance has its most important role in the internal improvement of outcomes against the prior performance of the hospital. As the Centers for Medicare & Medicaid Services (CMS) and state agencies choose to have public reporting of SSI rates through websites, the IP will be in the conflicted position of accurately reporting events, but realizing that the reward for completeness may be an unflattering identification of SSI rates which will cast their facility in a bad light. Public reporting should follow the guidelines provided by the Healthcare Infection Control Practices Advisory Committee.[16]

Table 37-8 Surgical Site Infection Profiles Relative to Risk and Severity

NHSN Risk Index	CDC Defined Severity of Infection		
	Superficial (S1)	Deep (S2)	Organ/Space (S3)
0 (R_0)	**R_0S_1** A 55-year-old (ASA 2) patient has transient serous discharge from a breast biopsy wound requiring no treatment after a 30-min breast biopsy.	**R_0S_2** A 21-year-old (ASA 1) man has a wound abscess of hernia incision requiring complete opening of the wound 3 days after 48-min elective repair of inguinal hernia.	**R_0S_3** A 61-year-old (ASA 2) patient has infected hip replacement prosthesis 4 days after a 2.5-hour total hip arthroplasty.
1 (R_1)	**R_1S_1** A 60-year-old (ASA 2) patient has a stitch abscess requiring suture removal 4 days after a 7-hour total thyroidectomy for a large papillary carcinoma.	**R_1S_2** A 63-year-old (ASA 4) patient with severe chronic lung disease has severe SSI requiring complete opening of wound on fifth postoperative day after a 2-hour total abdominal hysterectomy for endometrial carcinoma.	**R_1S_3** A 57-year-old (ASA 2) man has an emergency sigmoid colectomy for fecal peritonitis secondary to perforative diverticulitis. Intraabdominal abscess is drained on the seventh postoperative day.
2 (R_2)	**R_2S_1**A 64-year-old (ASA 4) patient has drainage of 30% of the length of a superficial groin infection on the fourth postoperative day after a complex 7.5-hour common femoral posterior tibial reconstruction of a severely ischemic lower extremity.	**R_2S_2** A 48-year-old (ASA 3) morbidly obese (480 lb) patient has an SSI requiring opening of the entire wound 4 days after an elective 4.5-hour Roux-en-Y gastric bypass.	**R_2S_3** A 65-year-old (ASA 3) patient has severe infection of spine and hardware 12 days after multilevel laminectomy and stabilization that required removal of infected instrumentation.

3 (R_3)	**R_3S_1** A 37-year-old (ASA 5) patient has an exploratory laparotomy for a gunshot wound of colon, pancreas, and left renal vein/artery; profound shock. He has a 5-cm area of locally drained, superficial wound infection on fifth postoperative day.	**R_3S_2** An 83-year-old (ASA 4) patient undergoes subtotal gastrectomy for perforated gastric carcinoma that has a deep SSI requiring opening of the entire wound on the sixth day after a 5.5-hour subtotal gastrectomy.	**R_3S_3** A 68-year-old (ASA 4) patient with severe congestive heart failure, aortic insufficiency, and staphylococcal endocarditis has a postoperative sternal infection with mediastinitis 5 days after a 7-hour aortic valve replacement.
ASA, American Society of Anesthesiologists; CDC, Centers for Disease Control and Prevention; NHSN, National Healthcare Safety Network.			

PREVENTION OF SURGICAL SITE INFECTIONS

Prevention of SSI follows the principles of counteracting those variables associated with causing infection. Thus, prevention consists of minimizing access of bacteria to the surgical site, neutralizing those bacterial species that do gain access to the wound, reducing adjuvant effects that create a local environment conducive to infection, and optimizing the efficiency of host responses to potential pathogens.

The preceding discussion identifies that the virulence of the contaminating bacteria at the surgical site is a significant variable in the development of SSI. The patient is colonized with resident microflora that has its intrinsic virulence and there are few if any measures that are going to modify microbial virulence. However, the duration of preoperative hospitalization before operation has been shown to affect the resistance of the patient's colonization and to be a factor in predicting higher rates of infection.[17] Thus, in the setting of an elective operation in the face of a recent or concurrent hospitalization, some consideration should be given to delaying the operation for several weeks.

Reducing Bacteria at the Surgical Site

Considerable interest has been focused on cleansing the surgical site before the patient arrives in the operating room in the hope that reductions in microbial counts on the skin surface at the time of the procedure will translate into lower SSI rates. These efforts have taken the form of antiseptic scrubs of the proposed surgical site and the use of total body baths or showers to diminish the presence of potential pathogens. These efforts have recently been summarized and analyzed and are still found lacking with respect to the reduction of SSIs.[18] There remains considerable interest in the use of preoperative cleansing of the proposed operative site and additional studies to evaluate alternative methods can be anticipated. Skin preparation in the operating room has a legacy going all the way back to Joseph Lister, and although there is general agreement that skin preparation with an antiseptic affords a reduction in infection, there continues to be debate about whether isopropyl alcohol, povidone-iodine, or chlorhexidine is superior. Chlorhexidine appears to have the best antibacterial action,[19] and has been most effective in the antiseptic preparation with alcohol for intravascular catheter placement.[20]

One systematic analysis gives a moderate endorsement for chlorhexidine over other topical antiseptics,

[21] and a meta-analysis of seven clinical trials concludes that chlorhexidine is superior to iodine preparations.[22] A recent randomized controlled trial demonstrated better reduction in SSIs with chlorhexidine-isopropyl alcohol when compared to povidone alcohol alone.[23] Chlorhexidine appears to be the preferred choice at this point not only because of antibacterial effect but also because of safety when use in the operating room compared to other agents (e.g., isopropyl alcohol). Removal of skin hair at the surgical site remains a continuing part of surgical lore that may not reduce SSI rates at all.[24] The process of removal may in fact increase the probability of SSI. Hair removal may clearly be necessary because of logistical problems at the site of operation. Removal of hair by any means the evening before the operation is likely to create local abrasions and trauma which become a nidus for infection.[25] Mechanical hair clippers are viewed as producing less local trauma at the time of skin preparation in the operating room immediately before the skin incision and are preferable to a razor.

Following antiseptic preparation of the proposed surgical site, other barrier measures have been used to prevent microbial access to the open wound. Circular wound protectors have been used to prevent environmental and endogenous bacteria from accessing the subcutaneous tissue during operations. There is a single analysis that favors the use of the wound protector in gastrointestinal and biliary surgery, but this practice remains an uncommonly used method for the prevention of SSI.[26] Plastic adherent drapes have been used over the proposed surgical site where the incision actually passes through the plastic and into the skin. A meta-analysis has not found any value in the reduction of SSIs even when iodine-impregnated plastic drapes were used.[27] Finally, a cyanoacrylate skin sealant has been proposed which is applied to the skin of the surgical incision site after skin preparation (and drying of the antiseptic) but before the actual incision. This seals any residual viable organisms within the skin structures from accessing the open incision. Studies to this point have demonstrated reduced bacterial colony counts in the wound after operations, but reductions in SSI rates require further study.

Many other methods are employed to restrict bacterial access to the open surgical wound. An appropriate surgical scrub of the hands and forearms is performed by all members of the surgical team that follow the guidelines provided by the CDC (Table 37-9).[28] Sterile drapes and sterile barriers of gowns, gloves, caps, and so forth are part of the standard practice in the operating room that forms the foundation of the code of conduct to avoid bacterial contamination of the wound. Standardized environmental guidelines for the operating room with respect to air handling have been issued.[29] Specialized systems such as laminar flow have been advocated but have not been documented to reduce infection rates.[30] Sterilization of surgical instruments should follow standard protocol,[31] and immediate use steam sterilization (formerly called "flash" sterilization) should be avoided except in unusual circumstances.[32] Restriction of operating room traffic avoids unnecessary airborne bacteria from the floor within the operating room from air currents created by movement.[33]

Table 37-9 Surgical Hand Antisepsis as Recommended by the Centers for Disease Control Healthcare Infection Control Practices Advisory Committee Guideline for Hand Hygiene in Healthcare Facilities

- Remove rings, watches, and bracelets before beginning the surgical hand scrub.
- Remove debris from underneath fingernails using a nail cleaner under running water.
- Surgical hand antisepsis using either an antimicrobial soap or an alcohol-based hand rub with persistent activity is recommended before donning sterile gloves when performing surgical procedures.
- When performing surgical hand antisepsis using an antimicrobial soap, scrub hands and forearms for the length of time recommended by the manufacturer, usually 2 to 6 minutes. Long scrub times (e.g., 10 minutes) are not necessary.
- When using an alcohol-based surgical hand scrub product with persistent activity, follow the manufacturer's instructions. Before applying the alcohol solution, prewash hands and forearms with a nonantimicrobial soap and dry hands and forearms completely. After application of the alcohol-based product as recommended, allow hands and forearms to dry thoroughly before donning sterile gloves.

Source: Boyce JM, Pittet D. Guideline for hand hygiene in health care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *MMWR Recomm Rep*2002;5:1-44.

Preventive systemic antibiotics are effectively used in many different surgical procedures. Basic animal models have demonstrated the benefits of preventive antibiotics in well-controlled studies when the drug was administered before or at the same time that microbial contamination occurred.[34,35] The antibiotics used had activity against the likely pathogens to be encountered. Antibiotics given following contamination had no impact on the natural history of the disease. Prospective clinical studies by Bernard and Cole[36] and Polk and Lopez-Mayor[37] demonstrated significance of preoperative administration compared to the administration of a placebo, and Stone and colleagues[38] identified that drugs begun after wound closure did not prevent infection. Preoperative antibiotics that have prolonged administration after the procedure do not improve SSI rates compared to antibiotics that are given only before the incision.[39,40]

Following these foundation publications of the 1960s and 1970s, an enormous number of prospective trials have confirmed the role of preventive antibiotics in a vast array of surgical procedures. It is generally recommended that preoperative preventive antibiotics be used when the operation enters a colonized body cavity where infection is a frequent event (e.g., intestinal tract, female genital tract, oropharyngeal cavity) or where infection rates are low but the consequences of infection at the surgical site are unusually severe (e.g., cardiac surgery, total joint replacement, synthetic vascular graft placement). While current evidence is not abundant, there is published support for using preventive antibiotics for clean operative procedures.[41] The practice of a single preoperative dose of an antistaphylococcal antibiotic (e.g., cefazolin) is a common and justifiable practice as long as the antibiotic is not continued into the postoperative period.

The National Surgical Infection Prevention (SIP) Project was a collaborative effort by the CDC and CMS that brought together experts in the area of surgical infection. Three performance measures were crafted to provide objective tools to direct the appropriate use of preventive antibiotics for surgical inpatients.[42,43] Those three measures are as follows:

1. The preventive antibiotic should be given within the 60-minute window before the surgical incision is made (except for vancomycin or fluoroquinolones where the window is 120 minutes).
2. The selected antibiotic should be consistent with recommendations made by the surgical organizations of the respective disciplines (Table 37-10).[44]
3. The antibiotics should be discontinued by 24 hours after the completion of the operative procedure (except for coronary artery bypass grafting, in which discontinuation should be at 48 hours).

Table 37-10 Surgical Care Improvement Project Recommended Prophylactic Antibiotic Regimen

Procedure	Approved Antibiotics
Coronary artery bypass graft, other cardiac surgery, or peripheral vascular surgery	Cefazolin, or cefuroxime, or vancomycin
Hysterectomy	Cefotetan, or cefazolin, or cefoxitin, or cefuroxime, or ampicillin/sulbactar
Hip or knee arthroplasty	Cefazolin, or cefuroxime, or vancomycin

Colon resection	Cefotetan, or cefoxitin, or ampicillin/sulbactar or ertapenem, or Cefazolin with metronidazole, or cefuroxime with metronidazole, or Ceftriaxone + metronidazole (only if SSI surveillance demonstrates Gram negative SSI resistant to first- or second-generation cephalosporins)
Principle procedure of hysterectomy + another code of colon surgery	Cefotetan, or cefazolin, or cefoxitin, or cefuroxime, or ampicillin/sulbactar or ertapenem
Source: Centers for Disease Control and Prevention (CDC). Specifications Manual for National Hospital Quality Measures for discharges. Available at: **http://www.jointcommission.org/specifications_manual_for_national_hospital_inpatient_quality_measures.aspx**.	

Evaluation of a large sample of patients from Medicare demonstrated that antibiotics are commonly not administered within the recommended 60-minute window, and that extension of postoperative administration beyond the 24-hour postoperative interval occurred in nearly 60 percent of cases.[45]

Measurement of performance and educational collaboratives improve compliance with the measures and reduce SSI rates.[46]The SIP Project has now transitioned into the Surgical Care Improvement Project (SCIP), in which it is hoped that the generation of additional evidence-based measures can further

improve SSI rates. Hospitals are now required to report rates of compliance with these several SCIP measures. Failure to report compliance results in payment penalties to the hospital by CMS. The rates of compliance are then publicly reported on the Hospital Compare website (http://www.medicare.gov/hospitalcompare/search.html).

A further expansion of preventive antibiotic process measures has been issued by QualityNet for ambulatory surgery. SCIP process measures apply for the ambulatory preoperative administration of antibiotics with respect to timing. Antibiotic recommendations have been made for specific ambulatory procedures (Table 37-11).[47] The use of preventive antibiotics in ambulatory procedures that are not covered by the QualityNet recommendations requires clinical judgment as to whether preventive antibiotics should be used at all, and which drug should be selected. Regardless of which drug is selected, the patient should not be continued on oral antibiotics for prevention after an ambulatory operation unless preexistent infection is present.

Table 37-11 QualityNet Outpatient Surgery Prophylactic Antibiotic Selection for Surgical Patients (OP-7)

Ambulatory Procedure	Approved Antibi Choices
Cardiac pacemaker or vascular	Cefazolin or cefuro
Orthopaedic or podiatric	Cefazolin or cefuro

Prostate biopsy	Quinolone, or first-generation cephalosporin, or second-generation cephalosporin, or third-generation cephalosporin, or aminoglycoside + metronidazole, or aminoglycoside + clindamycin, or aztreonam + metronidazole, or aztreonam + clindamycin
Penile prosthesis insertion, removal, revision	Ampicillin/sulbactar ticarcillin/clavulanat or piperacillin/tazobac or aminoglycoside first-generation cephalosporin, or aminoglycoside + second-generation cephalosporin, or aminoglycoside + vancomycin, or aminoglycoside + clindamycin, or aztreonam + first-generation cephalosporin, or aztreonam + secon generation cephalosporin, or aztreonam + vancomycin, or aztreonam + clindamycin

Percutaneous endoscopic gastrostomy	Cefazolin, or cefuroxime, or cefoxitin, or cefotet or ampicillin/sulbactar or cefazolin + metronidazole, or cefuroxime + metronidazole, or vancomycin
Laparoscopic-assisted abdominal or vaginal hysterectomy	Cefazolin, or cefuroxime, or cefoxitin, or cefotet or ampicillin/sulbac
Pubovaginal sling	First-generation cephalosporin, or second-generation cephalosporin, or ampicillin/sulbactar or quinolone, or aminoglycoside + clindamycin, or aminoglycoside + metronidazole, or aztreonam + clindamycin, or aztreonam + metronidazole

Outpatient head-neck	Cefazolin, or cefuroxime, or ampicillin/sulbactar or clindamycin ± aminoglycoside, or vancomycin
Outpatient neurological	Nafcillin, or oxacilli or cefazolin, or cefuroxime, or vancomycin, or clindamycin
*Vancomycin is acceptable with a physician/APA/Physician Assistant/Pharmacist documented justification for its use. Source: Centers for Disease Control and Prevention (CDC). Specifications Manual for National Hospital Quality Measures for discharges. Available at: **http://www.jointcommission.org/specifications_manual_for_national_hospital_inpatient_quality_measures.aspx**.	

The combined SIP/SCIP initiative has been in place for over a decade. Numerous reports have noted that no improvement in overall SSI rates has been identified,[48,49,50]and this has led to some concern whether the SCIP performance measures are valid.[51]The scientific evidence clearly points to the scientific validity of these measures, but it must be emphasized that SSI as a complication of care is the consequence of numerous clinical variables and its prevention requires numerous strategies to be in place. Failure to achieve reductions in SSIs through SCIP measures alone means that adherence to *all*methods for prevention must be observed. Without question poor surgical site preparation, or poor intraoperative technique, or breaches in infection prevention and control practices during the operation can all potentially trump the benefits of appropriate antibiotic administration.[52]

A particularly controversial area in the prevention of SSI is the use of mechanical preparation and oral antibiotics specifically in elective colon surgery. Mechanical preparation of the colon alone has been a long-standing part of surgical practice, although no evidence can be identified that mechanical cleansing alone reduces SSI rates. Several recent meta-analyses have verified the absence of benefit in the reduction of SSI by the use of mechanical bowel preparation alone.[53,54]However, the use of appropriate, poorly absorbed oral antibiotics following mechanical cleansing with oral neomycin and erythromycin (or metronidazole) has considerable evidence to support this practice, when used in conjunction with appropriately administered systemic antibiotics.[55,56]To be effective, mechanical preparation must be completed before oral administration of the antibiotics to avoid rapid transit of capsules/tablets through the gastrointestinal tract before dissolution and antibacterial effect.

The increased frequency of both community-associated and healthcare-associated MRSA has created some special problems and potential solutions for prevention of infection from these bacteria. First, cephalosporin antibiotics have been a mainstay in the prevention of SSIs, but this class of drug is not effective against MRSA. MRSA is becoming a bigger threat for SSI,[57] and this has resulted in increased usage of vancomycin for preventive indications, especially in hospitals where MRSA SSIs are frequent. In a large clinical trial in cardiac surgery, the use of vancomycin for prophylaxis proved no better than cefazolin because higher rates of methicillin-susceptible staphylococcal infection were identified in the vancomycin arm of the trial.[58] Resistance pressures loom for the ever-expanding vancomycin use. A newer systemic agent for the coverage of MRSA in surgical prophylaxis is desirable. Second, nasal colonization with MRSA is associated with increased rates of MRSA SSIs. This has led to the use of intranasal mupirocin for prophylaxis. Early studies have demonstrated some benefit with intranasal mupirocin.[59] Screening patients with nasal cultures for MRSA then results in the issues of who should receive intranasal mupirocin, and how long it should be continued. If patients receive appropriate systemic antibiotics for positive nasal cultures of MRSA, it makes sense that antibiotic prophylaxis must cover this organism. Intraoperative considerations in the prevention of SSI include wound irrigation and antibacterial suture. Low pressure irrigation with saline likely removes clot and debris within the wound that may account for some infections. Bacterial counts are not affected by saline irrigation of the wound soft tissues. Antibiotic irrigation has been pursued for many years and has not been demonstrated to be superior to the use of systemic antibiotics alone, except for a single study which demonstrated the benefit of topical kanamycin delivered via wound catheters in bariatric surgical patients.[60] Low concentration chlorhexidine gluconate (0.05 percent) has also been proposed for surgical incisional irrigation but has not been clinically evaluated.[61] Another intraoperative consideration is the use of antibacterial suture for wound closure. The antibacterial suture material may be monofilament nonabsorbable or absorbable polygalactin 910 which is coated with triclosan. Triclosan is generally a safe antiseptic with many years of use.[62] This antibacterial suture has been demonstrated to reduce bacterial colony counts on implanted suture, but clear evidence of effectiveness in the reduction of SSI remains to be demonstrated.

Enhancement of the Host

There have been a number of publications and considerable speculation over the last several decades about the use of drugs or natural enhancement agents that would bolster host defense for patients undergoing major operations and thus prevent infectious complications in the postoperative period. None have been identified. However, there have been a considerable number of investigations that are exploring the concept of optimization of the physiologic parameters of the host.

Supplemental oxygen administration is a potential intervention in surgical patients to prevent infections. Experimental evidence supports supplemental oxygen for the prevention of soft tissue infections.[63] Increase oxygen delivery may enhance phagocytic mobility and the efficient production of reactive oxygen intermediates to facilitate killing of microbes. Prospective clinical trials of oxygen supplementation by Greif and colleagues[64] and Belda and coworkers[65] demonstrated benefit in the reduction of SSIs in elective colon surgery; however, studies by Pryor and colleagues[66] demonstrated a failure of oxygen supplementation to benefit general surgical SSI rates. While considerable scientific evidence supports the positive immune effects of supplemental oxygen,[67] additional studies are needed to evaluate supplemental oxygen in the perioperative period.

Hypothermia is recognized as a complication of laparotomy and thoracotomy procedures, and several different insulating devices have been developed to maintain core body temperature during major operative procedures. Kurz and colleagues[68] demonstrated a significant reduction in SSI rates when core body temperature is maintained above 36.5°C, when control patients were allowed to have temperatures drift to 34.5°C. Measurement of core body temperature in elective colon surgery both during and immediately following the procedure has now become a measure in SCIP. More studies are needed to examine the benefits of body temperature control in other procedures.

Hyperglycemia has been associated with an array of negative influences on innate immunity.[69] Reduction of sternal wound infection rates from 2.0 to 0.8 percent in diabetic patients undergoing open heart surgery was demonstrated when glucose control was maintained at levels less than 200 mg/dL during the procedure.[70] A greater degree of hyperglycemia in cardiac surgery results in an increased odds ratio of infection.[71] It does appear to be the blood sugar control that is the risk factor and not the underlying diabetes condition.[72] Some evidence suggests that general and vascular surgery patients may similarly benefit from more rigorous glucose control.[73] Hyperglycemia may be a risk factor for infections and septic deaths in surgical ICU patients.[74] Recent evidence identifies that hypoglycemic events can be the consequence of attempts to reduce blood sugar in critical care patients.[75] Although considerable interest continues, additional studies are needed to define the limits of glucose reduction to achieve improvements in SSI rates.

Delayed Primary/Secondary Closure

Abdominal wounds are occasionally encountered where the degree of contamination is massive and the prospects for SSI in the postoperative period are quite great. Delayed primary closure is still an option rather than risk the consequences of potentially invasive infection that results in fascial necrosis and major reconstructive problems. It is a viable option for massive disruptions of the colon from a high-velocity gunshot wound of the colon, severe pancreatic abscess, and other similar circumstances of massive contamination. At operation, the skin and subcutaneous tissues are left open following fascial closure. The open wound is treated postoperatively with wet dressings as is detailed later, and delayed closure may be feasible on the fourth or fifth day following the operation. Many of the incisions that are managed in anticipation of delayed primary closure will not be closed because of exudates that form from the contamination at the original operation. These are usually best managed by secondary closure with granulation and contracture of the open incision.

MANAGEMENT OF SURGICAL SITE INFECTIONS

Despite the use of all available preventive strategies, SSIs still occur and require treatment. Each infected wound has a unique patient profile, unique characteristics of the operation, and potentially unique bacteriological features. The diversity of variables in the infected surgical site has resulted in a diverse number of options that are employed in management. The foundation principles in the management of the infected surgical site are: (1) open and drain the incision, (2) debride fibrinous debris and necrotic soft tissue, (3) remove foreign bodies, (4) implement antimicrobial management as needed, and (5) manage the open wound.

Opening the Wound

The skin sutures or staples should be removed and the infected area of the incision opened. All pus and inflammatory fluids should be evacuated. A surgical site may have a localized abscess that

necessitates only removal of skin sutures or staples for a limited length; however, many incisions will be entirely involved with the infection. Diffusely erythematous wounds with extensive induration should be opened completely. Pus should be evacuated mechanically and may require the use of local irrigation or suction. Evidence of a sinus tract means the wound needs further opening. After opening, the wound requires frequent dressing changes and inspection depending on the severity of the infection. Severe infections may have the dressings change and the wound inspected three to four times per day. The need for additional local drainage and debridement measures is also identified with dressing changes.

Cultures should be obtained at the time of drainage of the wound. In the past, it has not always been necessary to culture superficial SSIs, but the emergence of the community-associated MRSA has changed that position. These organisms are resistant to β-lactam antibiotics, and if antibiotic therapy becomes necessary, it will be important to identify the sensitivity pattern of recovered bacteria. Increasing numbers of patients have had prior recent hospitalization or have come from nursing home environments where resistant Gram-positive and Gram-negative organisms can be anticipated even for infections following elective procedures. It should be emphasized, and will be reiterated subsequently, that easily drained and superficial SSIs may require drainage as the only treatment, even if resistant organisms are cultured. Nevertheless, cultures provide data for epidemiological evaluation within the hospital. The decision to use antibiotics for treatment of the cultured bacterial pathogens is a clinical and not a microbiological decision, but the choice of which antibiotic will be driven by specific sensitivity results.

Debridement of the Wound

Infection at the surgical site results in the deposition of fibrin from the local inflammatory response. This fibrin matrix within the wound is quite impervious to antibiotic therapy and can be a protective haven for microbes against the phagocytic response of the host. Invasive infection results in varying degrees of thrombosis of the microcirculation, which then leads to necrosis of soft tissues at the surgical site. Necrotic tissue similarly must be removed.

Mechanical debridement can be performed at the bedside for many infections, but others may be sufficiently severe to require a return to the operating room. Fibrin can commonly be removed without the use of local anesthetics, while necrotic tissue is more problematic. Local anesthetics (no epinephrine added) may be required, in conjunction with systemic sedation, for debridement of tissue. More severe infections and those with extensive eschar on the wound interface will likely require a return to the operating room for general anesthesia and debridement.

Removal of Foreign Bodies

Foreign bodies associated with SSIs require removal as a general rule. Retained suture material is the most common and easiest foreign body to remove from the infected incision. Various synthetic mesh materials used in hernia repair pose a more challenging issue because removal in its entirety will doubtlessly pose major reconstructive issues subsequently. Vascular grafts, orthopaedic hardware, and other implanted devices will often require removal with infection and require clinical judgment in the decision of when to attempt management with the foreign body in place.

Antimicrobial Management

Antimicrobial management may consist of topical agents, systemic agents, or both. Topical antiseptics in the wound such as povidone-iodine or chlorhexidine are of unproven value[76] and at customary concentrations are potentially toxic to tissues and to host phagocytic cells.[77] Topical therapy used in burn

wound care with an established track record such as silver sulfadiazine or mafenide solution may be useful in severe SSIs in which marked erythema, induration, and soft tissue necrosis are present.

Systemic antibiotic therapy is not necessary in the majority of SSIs. Local drainage and debridement will result in rapid resolution of local evidence of inflammation. Severe erythema, induration, and soft tissue necrosis are generally findings that support the use of systemic antibiotics. The immunocompromised host and the patient with implanted prostheses (e.g., vascular graft, total joint prostheses) are also candidates for antibiotic therapy. Nafcillin or a first-generation cephalosporin is sufficient for methicillin-sensitive *S. aureus*infection. Trimethoprim-sulfamethoxazole or clindamycin is commonly chosen for community-associated MRSA infections. The healthcare-associated variant of MRSA will require vancomycin, linezolid, or daptomycin for treatment. With Gram-negative infections, culture results will be necessary to guide therapy, particularly because these organisms are usually part of a polymicrobial microflora. β-lactams or fluoroquinolones are commonly used for common Gram-negative pathogens (e.g., *E. coli*). Anaerobes are common participants in polymicrobial infections following colon or female genital tract operations, but cultures may not isolate these pathogens. Severe SSIs when anaerobes are suspected should be covered with antibiotics (e.g., metronidazole). Even when cultured, enterococcal coverage is employed only in the most severe of infections.

Wound Management

The open wound is managed in a fashion to let it continue to drain inflammatory fluids. Occlusive dressings of coarse, saline-soaked gauze are loosely placed into the wound. The open incision should not be packed tight, such that the wound is functionally converted into a closed one with tight packing. Lots of surgical lore has surrounded the use of the "wet-to-dry" dressing. Desiccation of the wound interface results in eschar formation from dried exudate and additional fat necrosis. The debriding action of dried gauze on an open incision is a myth of trivial value, compared to maintaining the moisture of the wound with saline-soaked, but loosely applied gauze, to avoid desiccation. Dressings are changed at least three times per day. Gentle mechanical debridement becomes the better management of these open wounds.

The wound vacuum-assisted closure (VAC) has been a major innovation in the management of open wounds. The wound VAC permits negative pressure drainage of the wound surface and permits rapid closure by secondary intention of the open healing wound. The wound VAC also provides an occlusive dressing to protect the open incision against secondary contamination.

Conclusions

SSIs will always be with us, particularly as we continue to push the frontiers for higher risk patients and adventuresome procedures. Techniques have been developed that reduce the rates for SSIs. Systemic antibiotics have been effective, but the continued evolution of resistant species poses an ongoing challenge. Optimization of physiological parameters appears to have great promise in reduction of infectious complications.

Future Trends

Future focus must be given to better control of skin contaminants gaining access to the wound. Topical antiseptics and preoperative cleansing of the proposed incision site should be better than current results indicate. Better antibiotics to address the emerging problem of MRSA and the evolving problem of

vancomycin-resistant species means that drug development and clinical trials must continue. A better method to detect MRSA colonization and better evidence for managing the preoperative surgical patient that has documented colonization is needed. The details of using supplemental oxygen and intraoperative temperature control must be better defined in clinical trials involving more diverse surgical procedures. Real-time glucose monitoring is crucial for ensuring that efforts of glucose control during and immediately following the operation are of benefit, and not a risk, for surgical patients.

Finally, we will only improve in the future when we know where we are at in the present. Accurate methods for surveillance and capturing significant infections following operative procedures need some new ideas and new directions. Linking postdischarge outcomes to ambulatory and inpatient surgical events is important so that improvements in outcomes from care redesign can be objectively evaluated. Providers, insurers, and government agencies need a more coordinated effort to track and analyze true outcomes of care, rather than process measures and surrogate indicators of quality performance.

International Perspective

SSIs have the same risk profiles and causative organisms in all of the countries of the world. On rare occasions, SSIs may be caused by microorganisms that are found in some parts of the world but not in others. Because most SSIs are caused by the host's own endogenous flora, there is great commonality in the bacteria cultured from SSIs worldwide. The greatest variation in the infectious agents from different countries is likely to be antimicrobial sensitivity rather than unique species. Clinicians must be aware of the sensitivity patterns of bacteria in their area and in their hospital to guide selection of antibiotics for both prevention and treatment of SSI.

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Section 6

Infection Prevention for Specialty Care Populations

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Burns

Author(s): Joan Weber, RN, BSN, CIC
Infection Control Coordinator

Shriners Hospitals for Children-Boston
Boston, MA

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Abstract

This chapter covers the etiological agents, epidemiology including outbreaks, surveillance, and isolation guidelines for the patient with burn injury. Clinical sepsis in the burn patient is defined. Specific sites of infection are covered in detail, including clinical manifestation, diagnostic tests, prevention, and treatment. These sites of infection include the burn wound, intravascular catheter-associated infection, suppurative thrombophlebitis, endocarditis, bloodstream infection, urinary tract infection, and pneumonia. Important complications of infection, future trends/research, and international perspectives as they affect the patient with burn injury are also provided.

Key Concepts

- Thermal injury results in significant suppression of the immune system.
- Loss of integument and immunosuppression after thermal injury results in a marked increase in the risk for complicating infections and sepsis.
- Sepsis is defined differently in burn patients because the burn itself causes metabolic changes that mimic sepsis in unburned individuals.
- Infection and sepsis are the most common causes of morbidity and mortality in burn patients.
- Infection prevention and control are more complex in preventing healthcare-associated infections in burn patients and must be carefully integrated into all aspects of burn patient care.

Background

Infection is the leading cause of morbidity and mortality in burn patients, despite improvements in care. Burns increase a patient's susceptibility to infection by damaging both the patient's physical and

immunological defenses. The skin is the largest organ of the body and constitutes the first defense against infection. When burned, the integrity of the skin barrier is broken and normally sterile sites become vulnerable to microbes. Blood flow becomes blocked, and defensins and other proteins are denatured by the heat and become a nutritive soup that supports, rather than discourages, microbial growth. In addition, internal physical barriers, such as those found in the gastrointestinal tract, "leak," allowing bacteria and their products, such as endotoxins, to translocate from the gut and populate normally sterile sites.[1,2]

With the skin barrier destroyed, and constant chronic exposure of the extensively burned patient to the environment, inflammatory mediators are released that change the baseline metabolic profiles of the burn patient. For example, in patients with large body surface area burns, the baseline temperature is reset to about 38.5°C, tachycardia and tachypnea can exist for months, and there are significant changes in white blood cell counts that make leukocytosis a poor indicator of sepsis.[3] Hence, burn healthcare providers have found it necessary to use other clues to identify sepsis in burn patients.

The importance of infection prevention has been recognized since organized burn care began. Some strategies such as strict aseptic technique, use of sterile gloves and dressing materials, wearing masks for dressing changes, and spatial separation of patients are still in use today. Other practices such as use of sterile sheets, routine use of prophylactic antibiotics, and infrequent dressing changes in the early post-burn period are no longer followed.[4] The integration of infection prevention practices into current burn care and treatment is widely recognized and is an integral and important part of the burn team concept. The effectiveness of infection prevention strategies depends on strict adherence to recommended policies and procedures by the entire burn care team. It also assumes that appropriate wound management, nutritional support, respiratory treatment, and other supportive care are provided.

Basic Principles

Types of wound infections in burn patients

1. Burn wound infections
    a. Invasive infections of unexcised eschar (see Centers for Disease Control and Prevention [CDC]/National Healthcare Safety Network [NHSN] definition of burn infections[5])
    b. Local or noninvasive burn wound infection:[6] Burn wounds that have a purulent exudate that is culture positive (if performed), require a change in treatment (which may include a change or addition to antimicrobial therapy, a removal of wound covering, or an increase in the frequency of dressing changes); and at least one of the following:
        i. Loss of synthetic or biologic covering of the wound
        ii. Changes in wound appearance, such as hyperemia
        iii. Erythema in the uninjured skin surrounding the wound
        iv. Systemic signs, such as hyperthermia or leukocytosis
2. Wound colonization in burn patients exists when bacteria or fungi multiply on the surface of a wound but do not invade viable tissue.
3. Other types of infections in burn patients are defined in the same manner as when they occur in other types of patients[5] (urinary tract infections, pneumonia, laboratory confirmed bloodstream infection, bloodstream infection secondary to infection at another site, cellulitis, impetigo, suppurative thrombophlebitis, endocarditis).

Infections In Burn Patients

The incidence of infection is higher in burn patients than in other patient groups, particularly in patients with larger burn injuries. In general, patients with small, uncomplicated burn injury (i.e., < 20 percent of total body surface area [TBSA] without smoke inhalation injury or preexisting health problems) are not at great risk of infection. As the percent of burn injury rises or is complicated by other injuries, the risk of infection increases.[4,7]

ETIOLOGICAL AGENTS

Beta-hemolytic group A streptococcus was the most frequent cause of infection and death in the preantibiotic era. When antibiotics became available, most patients were prophylactically treated with penicillin or a penicillinase-resistant β-lactam antibiotic at the time of admission to the hospital. Concerns about development of drug-resistant bacteria, however, have limited such use in many burn treatment facilities to surgery (e.g., burn wound excision) or treatment of actual or suspected clinical infection. Currently, this organism is not associated with major infectious complications in burn patients because of improved culturing techniques and prompt identification and treatment. However, if infection with this organism goes undiagnosed, it can cause a rapidly fatal invasive infection and graft destruction.[8]

Today, the most common causes of infections in burn patients are*Staphylococcus aureus*(including methicillin-resistant *Staphylococcus aureus [MRSA]*), *Pseudomonas aeruginosa, Acinetobacter baumannii,* enterococci (including vancomycin-resistant enterococci), and *Enterobacteriaceae*.[9,10]Both *S. aureus*and Gram-negative bacilli may frequently be resistant to many antibiotics including the aminoglycosides. Suppurative thrombophlebitis and endocarditis are frequently caused by *S. aureus*. Monitoring the microbial flora of patients within the burn unit at each facility is an important activity both for detection of drug resistance and assistance with therapeutic decisions. Experience with control and prevention of MRSA has been published.[11,12,13,14]Enterococci are frequently isolated from burn wounds and may cause severe burn wound infection and/or bloodstream infection with high mortality in patients with large injuries who are significantly immunocompromised.[15]Vancomycin-resistant enterococci (VRE) are increasingly being seen in burn intensive care units (ICUs). Antibiotics and other medications can generate and/or create a niche for these enterococci in the gastrointestinal tract.[16,17]Fungi may also cause burn wound infection, as well as fungemia and systemic fungal infection.[9]Fungal infections of the burn wound may be missed, unless burn wound biopsy specimens are subjected to histopathological examination, because cultures are positive in only about 30 percent of fungal burn wound infections.[18,19] Most fungal infections are caused by *Candida*, *Aspergillus*, *Trichosporon*, *Fusarium*spp., and the Zygomycetes (*Mucor*and Rhizopus spp.).[18,19,20,21,22]*Candida*is commonly part of the endogenous flora of the patient, whereas the other fungi are generally of exogenous (environmental) origin. A less common cause of burn wound infection is herpes simplex virus.[23,24,25]Both cytomegalovirus and herpes simplex virus infections are thought to be caused by reactivation of latent virus owing to the general immunosuppressed state of the host. Herpes simplex most commonly erupts in the head, neck, and partial thickness burn areas. Cytomegalovirus causes fever, but does not involve the burn wound.[26] Childhood viral diseases, such as varicella (chickenpox), can be life threatening for a burn patient because of the combination of reduced viral immunity and damaged skin.[25,27]Finally, human immunodeficiency virus (HIV) has been described in literature of the burn population.[28,29]

EPIDEMIOLOGY

The epidemiology of infection involves the source of the organisms, the mode of transmission, and a susceptible host. These are described in the following sections as they apply to the burn patient.

Reservoirs of Microorganisms

- Surfaces of burn wounds (collective burn wound surfaces of all patients in a burn care facility)
- Hands of personnel (carrier state)
- Inanimate environment,[9,30,31,32,33,34,35] including hydrotherapy equipment and associated plumbing, cooling blankets, mattresses, bedside computers, and reusable medical waste containers[36]
- Raw fruits and vegetables
- Colonic flora of patients

Modes of Transmission

Transmission is primarily direct or indirect contact through:

- Hands of personnel
- Fomites such as stethoscopes, electrocardiogram leads, and bed rails
- Hydrotherapy treatments[32] including hydrotherapy water and associated equipment and hands of hydrotherapy personnel (see Outbreaks Involving Burn Patients)

Airborne transmission is not as important in transmission of microorganisms among patients in burn units, although it has been reported.[37] It can be associated with fungal infection, particularly during construction in or around the burn unit. Airborne transmission has also been implicated in a varicella outbreak in a burn unit.[2]

Host Factors

Factors that influence the risk of colonization and/or infection after transmission has taken place (risk factors) include burn wound size, which appears to have a significant effect on the likelihood of colonization, with larger wounds at greater risk than smaller wounds,[35,38,39] development of resistance to topical antimicrobial agents,[36,40,41,42,43] and resistance to systemic antimicrobial agents.[44] Thermal injuries are often divided into major and minor burns based on the percent of TBSA burned. As a general rule, the American Burn Association considers major burns to be second- and third-degree burns > 10 percent TBSA in patients younger than 10 or older than 50 years old or > 20 percent TBSA in other age groups.[39]

A major consequence of severe burns is an overall immunosuppression of the patient. Every parameter of immunity, both humoral and cellular, has been shown to be abnormal at some time following a severe burn injury.[45] Skin, the first line of defense, is lost, and granulocytic activity is abnormal. Neutrophil oxygen consumption and chemotactic, phagocytic, and bactericidal activity are diminished.[46] Altered leukotriene generation may cause the observed neutrophil dysfunction.[47] There is an extremely complex interaction of several types of cells and several types of immunoregulatory systems.[48] Activation of the

arachidonic/prostaglandin cascade, the complement cascade, the cytokine cascade, and the neuroendocrine and metabolic regulatory systems all contribute to the immunosuppression after thermal injury. The release of these factors in response to burn injury appears to be chaotic and abnormal.[49]

Thus, after initial release of these factors owing to thermal injury, the immune system is primed. If another release of these immune mediators occurs in response to a second stimulus such as infection or endotoxin, the second release results in a greatly amplified response or "cytokine poisoning." This causes extensive tissue injury, immunosuppression, and multiple organ dysfunction.[48]Another factor that

has garnered more interest in recent years is the effect of blood transfusion mediating immunosuppression in addition to that caused by burn injury. Several retrospective studies in both adult and pediatric burn populations have noted this immunosuppressive effect with concomitant increase in infection. A prospective study to confirm this has been recommended.[50]

Open versus closed treatment may have an effect on colonization, but the role of the type of treatment is still not very well defined. Topical application of antimicrobial and antiseptic agents significantly limits growth of microorganisms on the burn wound surface; however, microorganisms may develop resistance to these agents. During five outbreaks, the epidemic strain was shown to be resistant, or relatively resistant, to the topical agent in use at the time of the outbreak.[36,40,41,42,43]

Smoke inhalation injury, which may accompany a burn injury, causes direct damage to the lining of the respiratory tract and increases the risk of pneumonia.[51]A dynamic ileus in the burn shock period

immediately after burn injury and altered gut permeability with large burn injury increase the risk of gut translocation of bacteria as well as passage of endotoxin. Inability to close burned eyelids and accumulation of exudate and debris in ear canals may also increase the risks of infection. Finally, the use of invasive devices (e.g., central vascular catheters, arterial catheters, endotracheal tubes, urinary catheters) increases the risk of infection in the burn patient. The risk of infection may be even greater than in other patient populations as these devices often must be inserted through or in close proximity to the burn wound and are often needed for extended periods of time to care for these patients.

OUTBREAKS INVOLVING BURN PATIENTS

Outbreak prevention and control represents a major challenge in units caring for burn patients.[4]

Reservoirs and modes of transmission associated with these outbreaks are presented in Table 38-1. In most cases, the importance of the colonized patient as a major reservoir for the epidemic strain was noted. Other important sources included hydrotherapy equipment, other patient care equipment, and environmental surfaces. Hydrotherapy, the use of a common treatment area, and contaminated equipment (i.e., mattresses) appear to pose a risk of cross contamination unique to the burn patient population. Hydrotherapy risks include water sources, which are frequently intrinsically contaminated by Gram-negative organisms and may be extrinsically contaminated by organisms from other patients. Adequate decontamination of equipment (e.g., tanks, plinths, shower tables, straps) is difficult to achieve, and culture techniques may be insufficiently sensitive to provide timely detection of contamination. Important contributing factors noted in several outbreaks included inadequate staffing and violation of transmission-based precautions and barriers among patients. In fact, in almost all cases, multiple factors contribute to the occurrence and perpetuation of outbreaks involving burn patients.

Table 38-1 Common Features of Outbreaks in Burn Units

Year	Organism	Modes of Transmission and Reservoirs

		Hand Carriage	Hydrotherapy and Related Equipment	Other Patient Care Equipment/Surfaces/Air	Staff Carriage	Breaks in Precaution Techniques	Staf Patt
1971[1]	*P. aeruginosa*	X	X	Sink faucetsTowel racks			
1975[2]	Salmonella typhimurium	X				X	
1976[3]	*Providencia stuartii*	X		X			
1979[4]	*P. aeruginosa*						
1979 [5]	*E. cloacae*	X	X				X
1979[6†]	MRSA*	X	X		X		
1981[7]	*P. aeruginosa**			Mattress			
1982[8]	MRSA*	X			X		
1982[9]	MRSA*	X	X		X		X
1983[10]	MRSA*	X	X	X			
1983[11‡]	MRSA*	X					
1985[12]	*A. calcoaceticus*	X	X	Mattress§ and other			
1992[13]	*P. aeruginosa**		X||				
1993[14]	*A. anitratus**			Mattress			
1993[15]	*P. aeruginosa*		X				
1994[16]	*P. aeruginosa**		X			X	
1994[17]	MRSA*	X		OR surfaces		X	
1994[18]	*P. aeruginosa**		X				
1995[19]	*A. baumannii**	X		X			
1996[20]	Group A streptococci				X		
1998[21]	*P. aeruginosa**						
1998[22]	*A. xylosoxidans*		X				
2000[23]	VRE		X	X			
2001[24†]	MRSA*		X||				
2001[25]	*A. baumannii**			Door handle and other	X		
2001[26]	*P. aeruginosa**						
2002[27†]	*A. baumannii**	X	X	X		X	

2002[28]	*A. baumannii**					
2003[29]	*A. baumannii*	X		X		X
2007[30]	*A. baumannii**		X	Room surfaces		
2008[31]	MRSA*			Aerosolization during dressing changes		
2011[32]	MRSA*				X	

MRSA, methicillin-resistant *Staphylococcus aureus*.
*Strains resistant to multiple antibiotics.
†Unit closed for decontamination and cleaning.
‡Unit permanently closed.
§Major reservoir identified.
||Hydrotherapy discontinued.

[1]Shulman JA, Terry PM, Hough CE. Colonization with gentamicin-resistant Pseudomonas aeruginosa, pyo type 5, in a burn unit. *J Infect Dis* 1971;124(suppl):S18–S23; [2]McHugh GL, Moellering RC, Hopkins CC, e al. Salmonella typhimurium resistant to silver nitrate, chloramphenicol, and ampicillin. A new threat in bur units? *Lancet*1975;1:235–240; [3]Wenzel RP, Hunting KJ, Osterman CA, et al. Providencia stuartii, a hospi pathogen: potential factors for its emergence and transmission. *Am J Epidemiol*1976;104:170–180; [4]Brid K, Kidson A, Lowbury EJL, et al. Gentamicin- and silver-resistant pseudomonas in a burns unit. *BMJ* 1979;1:446–449; [5]Mayhall CG, Lamb VA, Gayle WE Jr, et al. Enterobacter cloacae septicemia burn center: epidemiology and control of an outbreak. *J Infect Dis* 1979;139:166–171; [6]Crossley K, Landesman B, Zaske D. An outbreak of infections caused by strains of *Staphylococcus aureus* resistant t methicillin and aminoglycosides. II. Epidemiologic studies. *J Infect Dis*1979;139:280–287; [7]Fujita K, Lilly I Kidson A, et al. Gentamicin-resistant Pseudomonas aeruginosa infection from mattresses in a burns unit. *BMJ* 1981;283:219–220; [8]Locksley RM, Cohen ML, Quinn TC, et al. Multiply antibiotic-resistant *Staphylococcus aureus*: Introduction, transmission, and evolution of nosocomial infection. *Ann InternMed* 1982;97:317–324; [9]Arnow PM, Allyn PA, Nichols EM, et al. Control of methicillir resistant *Staphylococcus aureus* in a burn unit: role of nurse staffing. *J Trauma*1982;22:954–959; [10]Ruta WA, Katz EB, Sheretz RJ, et al. Environmental study of a methicillin-resistant *Staphylococcus aureus* epidemic in a burn unit. *J Clin Microbiol*1983;18:683–688; [11]Boyce JM, White RL, Causey WA, et al. Burn units as a source of methicillin-resistant *Staphylococcus aureus* infections. *JAMA* 1983;249:2803–2807; [12]Sherertz RJ, Sullivan ML. An outbreak of infections with *Acinetobacter calcoaceticus* in burn patients: contamination of patients' mattresses 258; [13]Tredget EE, Shankowsky HA, Joffe AM, et al. Epidemiology of infections with *Pseudomonas aeruginosa* in burn patients: the role of hydrotherapy. *ClinInfect Dis* 1992;15:941–949; [14]Habib J, Shurtleff S, Fish J, et al. Nosocomial transmission of aminoglycoside resistant Acinetobacter anitratus in a burn unit linked to mattresses. [Abstract] *Am J Infect Control* 1993;21:100; [15]Kolmos HJ, Thuesan B, Nielsen SV, et al. Outbreak of infection in a burns unit due to *Pseudomonas aeruginosa*originating from contaminated tubing used for irrigation of patients. *J Hosp Infect* 1993;24:11–2 [16]Richard P, Floch RL, Chamoux C, et al. Pseudomonas aeruginosa outbreak in a burn unit: role of antimicrobials in the emergence of multiply resistant strains. *J Infect Dis* 1994;170:377–383; [17]Sheridan Weber JM, Benjamin J, et al. Control of methicillin-resistant *Staphylococcus aureus* in a pediatric burn unit. *Am J Infect Control* 1994;22:340–345; [18]Richard P, Le Floch R, Chamoux C, et al.*Pseudomonas aeruginosa* outbreak in a burn unit: role of antimicrobials in the emergence of multiply resistant strains. *J Infect Dis* 1994;170:377–383; [19]Lyytikäinen O, Köljalg S, Härmä M, et al. Outbreak

caused by two multi-resistant Acinetobacter baumannii clones in a burns unit: emergence of resistance to imipenem. *J Hosp Infect*1995;31:41–54; [20]Gruteke P, van Belkum A, Schouls LM, et al. Outbreak of Grou streptococci in a burn center: use of pheno - and genotypic procedures for strain tracking.*J Clin Microbiol* 1996;34:114–118; [21]Hsueh P, Teng L, Yang P, et al. Persistence of a multidrug-resistant *Pseudomonas aeruginosa* clone in an intensive care burn unit. *J ClinMicrobiol* 1998;36:1347–13 [22]Vu-Thien H, Darbord JC, Moissenet D, et al. Investigation of an outbreak of wound infections due to Alcaligenes xylosoxidans transmitted by clorhexidine in a burns unit. *Eur J Clin Microbiol Infect Dis* 1998;17:724–726; [23]Falk PS, Winnike J, Woodmansee C, et al. Outb of vancomycin- resistant enterococci in a burn unit. *Infect Control Hosp Epidemiol* 2000;21:575–582; [24]E JM, McLeod JA, Al- Barrak AM, et al. An outbreak of methicillin-resistant *Staphylococcus aureus* on a bu unit: potential role of contaminated hydrotherapy equipment. *Burns* 2001;27:681–688; [25]Roberts SA, Find R, Lang SDR. Investigation of an outbreak of multi-drug resistant Acinetobacter baumannii in an intensive care burns unit. *J Hosp Infect* 2001;48:228–232; [26]Douglas MW, Mulholland K, Denyer V, et al. Multi-dru resistant Pseudomonas aeruginosa outbreak in a burns unit—an infection control study. *Burns* 2001;27:1 135; [27]Simor A, Lee M, Vearncombe M, et al. An outbreak due to multiresistant Acinetobacter baumanni a burn unit: risk factors for acquisition and management. *Infect Control Hosp Epidemiol* 2002;23:261–267 [28]Wong TH, Tan BH, Ling ML, et al. Multi- resistant Acinetobacter baumannii on a burns unit —clinical ris factors and prognosis. *Burns* 2002;28:349–357; [29]Bayat A, Shaaban H, Dodgson A, et al. Implications fo burns unit design following outbreak of multi-resistant Acinetobacter infection in ICU and burns unit. *Burns* 2003;29:303–306; [30]Zanetti G, Blanc DS, Federli I, et al. Importation of Acinetobacter bauma into a burn unit: a recurrent outbreak of infection associated with widespread environmental contamination. *InfectControl Hosp Epidemiol* 2007;28:723–725; [31]Dansby W, Purdue G, Hunt J, et al. Aerosolization of methicillin-resistant *Staphylococcus aureus* during an epidemic in a burn intensive care unit. *J Burn Care Res* 2008;29:331–337; [32]Boers SA, van Ess I, Eusera SM, et al. An outbreak of a multiresistant methicillin-susceptible *Staphylococcus aureus*(MR-MSSA) strain in a burn centre: The importance of routine molecular typing. *Burns* 2011;37:808–813.

SURVEILLANCE AND TRANSMISSION-BASED PRECAUTIONS GUIDELINES

Routine active surveillance culturing should be considered for patients with burn injury,[14,52]particularly those patients with large TBSA injury, to monitor the effectiveness of current wound treatment strategies, guide empiric antibiotic therapy, and detect any cross-colonization in a timely fashion so that further transmission can be prevented. Burn units should conduct their own risk assessment for the segments of their population who should be included in active surveillance culturing. If active surveillance culturing has not been previously done, it is suggested that all the patients be included for a selected period of time in culturing to determine who should continue to have these cultures. Burn patients who are in the hospital for more than a week should continue to have active surveillance culturing weekly to determine if any cross-transmission is occurring. Routine active surveillance culturing should include wound cultures (see Burn Wound Infection for more information) and may include other sites dependent on the risks of the particular burn population (e.g., respiratory cultures on admission for beta-hemolytic group A streptococcus carriage in children, carriage of multidrug-resistant organisms [MDROs] in selected patient groups).

Good infection prevention procedures using barrier techniques have been described and are important components of infection prevention. Lee et al.[53]found that use of simplified barrier precautions (e.g., hand washing, gloves, nonpermeable aprons, caps/masks) decreased healthcare-associated colonization

and saved resource utilization. Application of transmission-based precautions has been shown to vary by institution.[54] The following are examples of infection prevention strategies recommended by some burn treatment facilities:[4,55]

1. Emphasize hand hygiene before and after patient contact; although there are no data from burn units, one study in an intensive care nursery suggested that Gram-negative bacilli may be difficult to remove from the hands of healthcare personnel in an intensive care setting;[56] an antiseptic hand-washing agent or an alcohol rub should be used for hand hygiene in burn care facilities.
2. Healthcare personnel should use Standard Precautions to minimize or prevent exposure to bloodborne and other microorganisms (see also **29. Isolation Precautions (Transmission-based Precautions)**) when caring for all patients with burn injuries.
3. Protective apparel might include aprons or gowns donned before each patient contact and discarded immediately after leaving the patient's room. This is particularly important for patients with larger percentage burn injuries.[57]
4. Change gloves when soiled and before continuing with care at another site on the same patient.
5. Ensure appropriate cleaning and disinfection of reusable equipment before use on another patient.
6. Restrict plants and flowers at the bedside of patients with burn injuries for they may harbor Gram-negative organisms, such as *Pseudomonas* spp. and fungi.
7. Restrict nonwashable toys (e.g., stuffed animals, cloth objects) that can harbor bacteria and are difficult to disinfect.

Additional precautions, such as a private room or physical separation from other patients through an enclosed bed space, should be considered for those patients with larger burn injuries (i.e., > 25 to 30 percent TBSA), due to the risk of an immunosuppressive state and for patients colonized with MDROs.[4,58,59]

Burn Wound Infection

CLINICAL MANIFESTATIONS

The most common clinical signs of an invasive burn wound infection are the appearance of hyperthermia or hypothermia, changes in mental status (disorientation, lethargy, coma), adynamic ileus, glucose intolerance with hyperglycemia, respiratory distress syndrome, and oliguria.[60,61] In addition, a drop in platelets and a rise in C-reactive protein have been reported as early indicators of invasive infection in burn patients.[62,63] The burn wound may have dark brown, black, or violaceous discoloration, hemorrhagic discoloration of subeschar tissue, edema and violaceous discoloration of unburned skin at wound margins, and unexpectedly rapid eschar separation.[61] Invasive infection of unexcised burn wounds is a rare occurrence today with the advent of early burn wound excision and closure.

Local or noninvasive wound infection occurs in burn wounds, donor sites, and grafted wounds, which have not epithelialized. They have a purulent exudate, require a change of treatment, and can include a loss of synthetic or biological covering of wound, change in wound appearance such as hyperemia, erythema in the uninjured skin surrounding the wound, and systemic signs such as fever or leukocytosis. This is the more common type of wound infection encountered in burn patients.[64]

Burn wound cellulitis occurs in uninjured skin surrounding the burn wound or donor site; it is associated with erythema, localized pain, tenderness, swelling, and heat. Burn wound impetigo is a bacterial infection involving a loss of epithelium from a previously reepithelialized surface that is not related to inadequate excision of the wound, mechanical disruption of the graft, or hematoma formation.[65]

DIAGNOSTIC TESTS

Blood tests may reveal thrombocytopenia, leukocytosis, leukopenia, or elevated circulating C-reactive protein levels, any of which may indicate burn wound infection. In the past, the approach to diagnosis of invasive burn wound infection was quantitative culture or histopathological examination of a burn wound biopsy. An infection was diagnosed when there were > 10^5microorganisms per gram of burn tissue;[66] however, results of this test correlated poorly with the actual presence of a clinical burn wound infection. When there are < 10^5microorganisms per gram of burn tissue, burn wound infection is highly unlikely.[67]

Using histopathological examination, burn wound infection was diagnosed when microorganisms were observed invading the viable tissue below the eschar. Today, in the era of early burn wound excision and closure, diagnosis of invasive burn wound infection is made by clinical signs and symptoms and, when possible, histopathological examination of a burn wound biopsy specimen with evidence that microorganisms are invading viable tissue. The causative microorganism(s) are identified by culture of purulent exudates or tissue.[6,67]

A probable diagnosis of invasive burn wound infection may be made when the same microorganism cultured from the surface of the burn wound is also recovered from the blood (in the absence of other infected sites that could give rise to bacteremia). Fungal infection of the burn wound can best be diagnosed by histopathological examination of a burn wound biopsy specimen, because fungi can be recovered from only 30 percent of burn wound biopsy cultures.[18]

PREVENTION

Development of topical antimicrobial agents for application to the burn wound was a major breakthrough in improving the survival of burn patients.[68]These agents retard the multiplication of microorganisms on the burn wound surface.[60]Agents that are used include silver nitrate (associated with loss of sodium and potassium), mafenide acetate (causes pain and use is complicated by metabolic acidosis), and silver sulfadiazine (associated with leukopenia). Newer dressing materials containing silver are also available and are used to control proliferation of microorganisms in a variety of wounds. Just as some microorganisms have developed resistance to systemic antimicrobials, they have also shown some resistance to topical agents, such as neomycin, silver sulfadiazine, and bacitracin.[40]

Hydrotherapy continues to be used routinely in some facilities, despite a lack of scientific evidence supporting its benefit. Outbreaks, particularly among patients with large (> 30 percent surface area) burn injuries, have been associated with this therapeutic modality (see Outbreak, Table 38-1) and some have advocated its discontinuation in favor of local wound care with sterile saline solution.[32]However, in 2010, a survey of 59 burn centers revealed that 83 percent used some form of hydrotherapy with 45 percent using immersion hydrotherapy.[69]If hydrotherapy is used, shower tables are generally thought to be associated with less risk than the immersion method. However, outbreaks may occur even when shower tables are used.[70]When immersion hydrotherapy is used, consider the use of plastic liners with air channels for agitation of the water in hydrotherapy tanks rather than mechanical agitators. No

published standards or guidelines are available on methods of effectively decontaminating hydrotherapy tanks used in patients with open burn wounds. Disinfection protocols generally describe rinsing the tanks or equipment with a 1:10 or 1:20 dilution of 5.25 percent sodium hypochlorite in water (concentration of bleach when purchased). Hydrotherapy water and equipment should be considered in a monitoring program for bacteria by sampling the water from the tanks and obtaining swab cultures from faucets, drains, and aerators.[4]

Early excision and closure (grafting) of the burn wound with removal of nonviable tissue and coverage of the site reduced burn wound infection in two published trials in pediatric burn patients.[70,71] Few randomized controlled trials of early excision and closure versus conventional therapy (allowing the eschar to separate on its own, followed by skin grafting) in adults have been published. One trial did not mention burn wound infections,[71] whereas one trial found a reduction in burn wound infections only in patients with burns of 0 to 15 percent of body surface area,[72] and another trial noted no difference in septic days between patients who were treated with early excision and those treated with conventional therapy.[73] Although data in the literature on the effectiveness of early excision and closure in reducing burn wound infection rates are absent except for burns < 15 percent total body surface area, there seems to be a consensus among burn surgeons that burn wound infection rates are substantially decreased by early excision and wound closure.[74,75,76]

TREATMENT

If invasive burn wound infection is suspected, there seems to be a consensus among burn surgeons that patients should have immediate surgical excision of the infected wound, as well as a change in the topical antimicrobial treatment and institution of a broad-spectrum antibiotic combination,[3] which might include an antistaphylococcal penicillin for MRSA or vancomycin if there is a concern that MRSA may be causing the infection, and either an antipseudomonal cephalosporin or a penicillin/beta-lactamase inhibitor combination. Knowledge of burn unit-specific susceptibility patterns will also be useful in selecting empiric therapy. It is generally stated that antimicrobial agents attain low concentrations in burn eschar because of its avascularity; however, gentamicin and tobramycin attain therapeutic concentrations in burn eschar without using excessively high doses.[77] These antibiotics may also be used in combination with a third-generation cephalosporin or antipseudomonal penicillin for treatment of burn wound infections caused by Gram-negative bacilli.[78]

If a specific causative microorganism can be identified, antibiotic therapy should be modified based on the identity and antimicrobial susceptibility of the causative microorganism(s). If a specific causative microorganism cannot be identified, broad-spectrum coverage should be continued until a specific microbiologic diagnosis can be made or the infection is cleared. The clinical and microbiological course of the patient must constantly be monitored because superinfection with a resistant microorganism may occur during therapy.[44] The drug of choice for burn wound infection owing to MRSA is vancomycin. For treatment of enterococcal burn wound infection, gentamicin should be combined with penicillin, ampicillin, or vancomycin. VRE are usually of the species *Enterococcus faecium*, which are relatively more resistant to penicillin and ampicillin. Infections caused by these organisms may be treated with linezolid or quinupristin/dalfopristin. For Gram-negative infections, the treatment depends on the type of Gram-negative organism present, if known. For enteric Gram-negative organisms, a combination of an aminoglycoside plus piperacillin or other extended spectrum beta-lactams may be recommended. For nonenteric Gram-negative organisms, an aminoglycoside plus piperacillin or ticarcillin may be

recommended. Given the increasing incidence of MDROs, choice of drugs should also be guided by antimicrobial susceptibility reports from the individual hospital or antimicrobial susceptibility reports for the specific pathogen. The drugs of choice for fungal burn wound vary depending on the specific etiological agent. Drugs now available include amphotericin B, fluconazole, itraconazole, voriconazole, posaconazole, and caspofungin. Excision of the infected burn wound may also be necessary to control the infection, particularly when the infection is caused by fungi.[18,60]

Intravascular Catheter-Associated Infection, Suppurative Thrombophlebitis, And Endocarditis

EPIDEMIOLOGY

Intravascular catheters—including peripheral intravenous catheters; subclavian, femoral, and jugular central catheters; percutaneously inserted central catheters; and Swan-Ganz catheters—frequently become sites of infection in burn patients. These devices may have to be introduced through the burn wound in patients with large burn injuries. Even when they can be introduced through normal skin, there is a large reservoir of microorganisms on the nearby burn wound that can easily be transferred to the catheter site by the hands of personnel or the patient. There may be further contamination at intravascular cannulation sites if patients receive hydrotherapy and the sites are contaminated by hydrotherapy water.

Suppurative thrombophlebitis is a more severe form of intravascular catheter-associated infection. Prolonged cannulation of veins with long-standing infection may lead to suppurative thrombophlebitis with invasion of the venous wall by microorganisms and a venous lumen filled with purulent exudates. *S. aureus*is the most common cause, and *S. aureus*bacteremia may lead to endocarditis. Both suppurative thrombophlebitis and endocarditis may be clinically silent except for systemic signs of sepsis. Burn patients are particularly susceptible to this complication due to the length of time that patients with large injuries may require central venous catheter access.

CLINICAL MANIFESTATIONS

Intravascular catheter-associated infections are associated with fever, signs of inflammation at the intravenous catheter site including erythema, tenderness, and purulent drainage. Frequently, there may be no signs of inflammation at the catheter site.

Suppurative thrombophlebitis is associated with fever, signs of septicemia, and edema of the extremity. Other clinical signs are frequently absent. There may be purulent drainage from the catheter site, or purulent drainage may be milked from old intravenous catheter sites.[79,80]

Endocarditis is associated with fever, and other signs of endocarditis are frequently absent. The diagnosis is often made at autopsy.[81]

DIAGNOSTIC TESTS

Purulent drainage from the intravenous catheter site is evidence of a catheter wound infection. In the absence of purulent drainage, the best procedure for diagnosis is removal of the catheter and semiquantitative culture of the catheter on an agar plate.[82,83]

Diagnosis of suppurative thrombophlebitis may be suspected by drainage of purulent exudate from a catheter site or when purulent exudate can be milked from old catheter sites.[79,80] Definitive diagnosis is made by surgical exploration with demonstration of purulent exudate in the lumen of involved veins or evidence of invasion of the vein wall by microorganisms on histopathological examination of a vein wall biopsy specimen.

Clinical signs of endocarditis include cardiac murmur and peripheral stigmata of endocarditis. Clinical signs may also be absent. Demonstration of high-grade bacteremia by multiple positive blood cultures in the absence of evidence of other intravascular foci of infection such as suppurative thrombophlebitis or intravascular catheter-associated infection is strongly indicative of bacterial endocarditis.[81] The diagnosis can be confirmed by echocardiography.

PREVENTION

Practices for prevention of intravenous catheter infection are challenging in the burn population because of the length of time these catheters are required and the large open wounds colonized with potential pathogens. When possible, central line bundle practices, particularly for insertion, should be followed (see **34. Intravascular Device Infection**). When possible, avoiding intravenous cannulation through the burn wound may reduce the risk of intravascular device-associated infection. Use of meticulous aseptic technique for inserting and maintaining intravenous catheters should always be done wherever the catheter is placed. Duration of catheter placement and optimum frequency of catheter change has not been definitively determined. Some burn centers change catheter sites every 3 days, whereas others support less frequent catheter replacement protocols.[84,85] In addition, many burn units are now advocating antimicrobial-coated catheters as another method to avoid infections associated with central venous catheters.[86] Care of insertion sites for catheters placed near or through the burn wound, when occlusive dressings cannot be used, has also not been studied. Two surveys have recently been published describing the wide variation in intravascular catheter practices among burn units in the United States.[87,88] Prevention of thrombophlebitis and endocarditis is the same as that for prevention of intravascular catheter-associated infection.

TREATMENT

When an intravascular catheter is suspected as a source for infection, it should be removed and cultured semiquantitatively and at least two blood cultures should be taken, preferably from peripheral venous sites. The patient should be started on broad-spectrum antimicrobial therapy until culture results are available. Antibiotic therapy can then be modified according to the identity and susceptibility of the causative microorganism.

The most important therapeutic modality for suppurative thrombophlebitis is surgical excision. The patient should be started on broad-spectrum antimicrobial therapy, which should include a drug effective against *S. aureus,* including MRSA, pending results of cultures.

Treatment of endocarditis depends on the identity and susceptibility of the causative microorganism recovered from blood cultures. Endocarditis should be treated for 6 weeks.

Bloodstream Infection

EPIDEMIOLOGY AND CLINICAL MANIFESTATIONS

Bloodstream infection (BSI) and central line-associated bloodstream infection (CLABSI) are more common in burn patients than in other patient groups because of bacterial colonization of the large body surface area of the burn. Seeding of the bloodstream may also occur with wound manipulation.[89] BSI may be either a laboratory confirmed bloodstream infection (LCBI) or a bloodstream infection secondary to an infection at another site. LCBI most often arises from CLABSI. LCBI may also arise from manipulation of the colonized, although not infected, burn wound or from translocation of gut bacteria. Secondary BSI most commonly arises from the infected burn wound but, as in other patients, may also arise from urinary tract infections or pneumonia. Clinical manifestations include fever, chills, hypotension, and oliguria.

DIAGNOSTIC TESTS

Diagnosis of BSI includes one or more positive blood cultures with a microorganism that is considered a pathogen (i.e., not a microorganism that is frequently a contaminant such as *Staphylococcus epidermidis, Bacillus*spp., or diphtheroids). For common skin contaminants to be considered a cause of bacteremia, the patient must have fever > 38°C or chills or hypotension and two or more positive cultures taken on separate occasions. (See CDC definitions for LCBI.[5]) There is considerable concern in the burn community regarding the applicability of this CDC definition to the burn population, as a single positive blood culture for nonskin contaminants may represent either CLABSI, transient bacteremia from manipulation of the colonized burn wound, or translocation of gut bacteria. The following definitive diagnosis of CLABSI is given to be able to better delineate these differences:

- Isolation of the same microorganism from a semiquantitative culture of a catheter segment and the blood of a patient who has accompanying clinical signs of bloodstream infection without another apparent source is required.[82,83]
- Transient bacteremia is temporally related to cleaning or debridement of the burn wound.

PREVENTION AND TREATMENT

Prevention includes preventing intravascular catheter-associated infection (see previous section), as well as preventing infections at other body sites including the burn wound, which may give rise to bloodstream infection.

Suspected bacteremia in a burn patient should be treated with broad-spectrum antimicrobial therapy pending the results of blood cultures. Uncomplicated bacteremia should be treated for 2 weeks.

Urinary Tract Infections

EPIDEMIOLOGY AND CLINICAL MANIFESTATIONS

The epidemiology is similar to that of urinary tract infections in other types of patients.[90] Added risk factors include the large reservoir of microorganisms on the surface of the burn wound and contamination of the external meatus by hydrotherapy water. In addition, urinary catheters may be needed for prolonged periods of time in patients with large burn injuries, increasing the risk of developing a catheter-associated urinary tract infection (CAUTI).

Clinical manifestations include fever, urgency, frequency, dysuria, and suprapubic tenderness. Signs of bacteremia may appear if microorganisms invade the bloodstream.

DIAGNOSTIC TESTS

Diagnosis of UTI in burn patients is the same as in other patient populations[5](See **33. Urinary Tract Infection**).

PREVENTION AND TREATMENT

Meticulous infection prevention and control practices should be practiced for care of patients with urinary catheters in place (see **33. Urinary Tract Infection**for information on the CAUTI bundle). It is important to prevent contamination of the external meatus from contact with hydrotherapy water. Remove urinary catheters as soon as they are no longer needed.

If UTI is suspected, urinary catheters should be removed as soon as possible. Therapy should be selected on the basis of antimicrobial susceptibility of the causative microorganism. An antimicrobial agent must be chosen that attains a therapeutic concentration in the urine.

Pneumonia

EPIDEMIOLOGY AND CLINICAL MANIFESTATIONS

With the decline in invasive burn wound infection, pneumonia has become the most common cause of significant morbidity and mortality in burn patients. The epidemiology of pneumonia is similar to that of pneumonia in other types of patients. Before availability of effective topical antimicrobial agents, burn patients frequently developed hematogenous pneumonia from their burn wounds.[91]Today, most cases of pneumonia in burn patients develop in the same way as pneumonias in other patients with microorganisms first colonizing the oropharynx and then being aspirated into the lungs. Risk factors for pneumonia in burn patients include endotracheal intubation and mechanical ventilation and smoke inhalation injury.[92,93]

Clinical manifestations include fever, cough, and purulent sputum. Bacteremia may develop with accompanying clinical signs.

DIAGNOSTIC TESTS

Diagnosis of pneumonia in patients in burn ICUs can be problematic as many of the signs and symptoms are similar to noninfectious conditions such as acute respiratory distress syndrome (ARDS), which can and often does occur in this group of patients. Discussion with the clinician caring for the patient may be required to determine if the patient has pneumonia or other clinical diagnosis. This is particularly true for patients with smoke inhalation injury for which discrimination between what is pneumonia and what is ARDS can sometimes be difficult. CDC definitions for ventilator-associated event or ventilator-related pneumonia in adult and pediatric patients should be followed[5](see **36. Pneumonia**).

PREVENTION

Provide excellent care for endotracheal tubes and tracheostomies, including careful endotracheal suctioning using aseptic technique. Frequency of suctioning may need to be increased in the early post burn period to remove the soot and other debris that may accompany a smoke inhalation injury. Chest physiotherapy, turning, coughing, and deep breathing should be done routinely. Patient care should be organized to provide for contact with clean areas first (oropharynx, tracheostomy) followed by care of areas with higher degrees of contamination (burn wound, urinary drainage system). Breathing circuits

should be changed only when visibly soiled or mechanically malfunctioning.[94] Condensate from the ventilator circuit should be prevented from draining back into the patient's tracheobronchial tree.[94,95] The in-line medication nebulizer reservoirs should be cleaned, disinfected, and rinsed with sterile water or air-dried after each treatment. Nebulizers should undergo sterilization or high-level disinfection between patients.[94,96] Patients on enteral feedings should be kept in the semi recumbent position at an angle of 30 to 45 degrees, if there are no medical contraindications, to decrease the risk of aspiration.[94,97]

Patients should also have interruption of sedative administration to aid in extubation and decrease the duration of intubation.[98,99]

TREATMENT

Antimicrobial agents should be selected on the basis of the results of cultures of expectorated sputum or tracheobronchial secretions obtained by suction in nonintubated patients or cultures of lower respiratory tract secretions obtained by fiberoptic bronchoscopy in intubated patients. In some cases, tracheobronchial secretions may not be available for culture or tracheobronchial secretions obtained by expectoration or endotracheal suctioning may yield multiple species on culture. After specimens of respiratory secretions have been obtained and blood has been drawn for two blood cultures and these specimens have been sent for culture, the patient should be started on broad-spectrum antimicrobial therapy to cover all possible pathogens pending results of cultures and susceptibilities.[100,101,102]

Conclusions

One of the most important complications of infection is death resulting from overwhelming sepsis. Renal failure is an important complication and may result from sepsis, hypotension, and the nephrotoxic effects of aminoglycoside antibiotics that are used to treat Gram-negative infections in these patients. Burn wound infection may convert a partial-thickness burn into a full-thickness burn. Finally, superinfection of the burn wound by a microorganism resistant to the therapeutic agent in use may occur during therapy.

Future Trends

Future studies are needed to determine the following:

- Benefits of early excision and grafting in prevention of wound infection, other infection, and other noninfectious complications in adults.
- Appropriate use of hydrotherapy with indications of which patients should or should not undergo this therapy.
- Modification of the central line bundle infection prevention practice for the unique aspects of burn patients including: optimum frequency for central venous catheter change and best type of line care strategies for nonocclusive care when the insertion site is near or through burn.
- Care of burn patients outside of the burn unit or care of nonburn patients within the burn unit in the era of managed care.
- Development of infection definitions that are applicable to burn patients.

A consensus conference composed of experts from the American Burn Association met to define sepsis and infection in burns. Although excellent standards exist for other diagnoses, standardized definitions

for infection and sepsis in burn patients have never been developed. The American Burn Association Consensus Conference to Define Sepsis and Infection in Burns states that sepsis is a change in the burn patient that triggers the concern for infection. The definition is age dependent, and the indicators for infection include at least three of the following:[3]

- Temperature > 39º or < 36.5°C
- Progressive tachycardia
  - Adults > 110 beats per minute (bpm)
  - Children > 2 standard deviations (SD) above age-specific norms (85 percent age-adjusted maximum heart rate)
- Progressive tachypnea
  - Adults > 25 bpm not ventilated
- Minute ventilation > 121/min ventilated
  - Children > 2 SD above age-specific norms (85 percent age-adjusted max respiratory rate)
- Thrombocytopenia (will not apply until 3 days after initial resuscitation)
  - Adults < 100,000/mcL
  - Children < 2 SD below age-specific norms
- Hyperglycemia (in the absence of preexisting diabetes mellitus)
- Untreated plasma glucose > 200 mg/dL or equivalent mM/L
- Insulin resistance—examples include:
  - > 7 units of insulin/hr intravenous drip (adults)
  - Significant resistance to insulin (> 25 percent increase in insulin requirements over 24 hours)
- Inability to continue enteral feedings > 24 hours
- Abdominal distention
- Enteral feeding intolerance (residual > 150 mL/hr in children or two times feeding rate in adults)
- Uncontrollable diarrhea (> 2,500 mL/d for adults or > 400 mL/d in children)

In addition, it is required that a documented infection (defined as the following) is identified:

- Culture positive infection, or
- Pathologic tissue source identified, or
- Clinical response to antimicrobials.

International Perspective

This chapter was written predominantly as a discussion of infection prevention in burn care in the developed world, particularly the United States. Factors in caring for patients in other areas of the world, such as various aspects of the patients' microbial flora, can impact infection prevention practice. Intestinal helminths and parasites are quite common in patients from tropical areas, whereas parasitic infestation is relatively rare in most U.S. patients.[103]Diseases, such as tuberculosis, might be more prevalent in foreign patients. Additionally, depending on the availability of antibiotics and antibiotic treatment practices in other countries, bacteria from patients from these countries can have quite different antibiograms and often show markedly increased resistance.[104]Finally, socioeconomic factors in

countries with limited resources can result in burn patients who suffer from malnutrition and have limited access to medical resources. Despite these differences, the principles of infection prevention for burn care outlined in this chapter should basically remain the same—that is, recognize that the burned patient is at increased risk for infection and minimize that risk, to the extent possible, by following the guidelines given. Following these guidelines is quite possible when caring for foreign patients in a U.S. facility in which extra attention may be given to nutrition and to microbial and disease surveillance. However, it is recognized that following only the most basic of the guidelines, such as hand hygiene, may be all that is feasible in some countries with limited resources.

Supplemental Resources

American Burn Association. Available at: **http://www.ameriburn.org**.

International Society for Burn Injuries. Available at: **http://www.worldburn.org.**

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Dialysis

Author(s): Sylvia Garcia-Houchins, RN, MBA, CIC
Director, Infection Control Program

University of Chicago Medical Center
Chicago, IL

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Abstract

Dialysis-associated infections include access site infections, bacteremia, peritonitis, and bloodborne pathogens. In order to prevent these types of infections, infection preventionists should be familiar with the recommendations to reduce the risk of access-associated infection, hemodialysis water processing and distribution systems, medication safety, the basic concepts of hemodialyzer reuse and the reuse program in their own facility, and steps for prevention of bloodborne pathogen transmission in the dialysis setting. This chapter provides basic and best practice information on each of these areas as well as a reference for practitioners to use for comparison of local practice. In addition, action steps to take in response to potential scenarios and dialysis resources are provided.

Key Concepts

- Dialysis or renal replacement therapies are procedures that replace the normal functions of the kidney by removing metabolic waste products through diffusion and hydraulic pressure gradients. Use of an artificial (hemodialyzer) or a natural (peritoneum) semipermeable membrane allows passage of some molecules while passage of other molecules is restricted. Blood and dialysate pass on opposite sides of the membrane but do not mix. Molecules that can pass through the semipermeable membrane move from the area of higher concentration to that of lower concentration. Dialysis can be used when acute renal failure develops or as a life-sustaining treatment with end-stage renal disease until the patient undergoes transplantation or dies. Renal replacement therapy may be used to remove cytokines that are present in blood during septic shock or for patients who are too hemodynamically unstable to undergo hemodialysis.
- Hemodialysis removes toxins, electrolytes, and fluid by circulating the patient's blood through a hemodialyzer (Figure 39-1). During intermittent or chronic hemodialysis, patients are usually scheduled to receive hemodialysis treatments for 2 to 4 hours, three times per week.[1]Processed or

highly purified water, often called "product water," is needed to perform hemodialysis.[2] Hemodialysis is performed using a machine that has internal fluid pathways that mix dialysate components (processed water, bicarbonate, and acetate), passes them through the dialysate pathway of the hemodialyzer, and then discards them into a drain (single pass). The dialysate must also meet Association for the Advancement of Medical Instrumentation standards.[3]

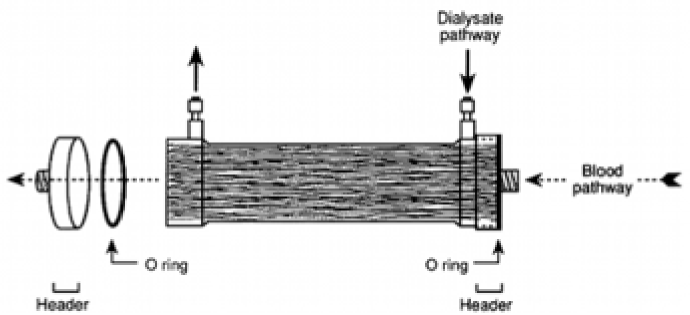

Figure 39-1.

Schematic representation of the Hemoflow F-80 dialyzer. (From Flaherty JP, Garcia-Houchins S, Chudy R, et al. An outbreak of gram-negative bacteremia traced to contaminated O-rings in reprocessed dialyzers. *Ann Intern Med* 1993;119:1072–1078.)

View Image

Although new Association for the Advancement of Medical Instrumentation standards for processed water and dialysate were adopted in 2011,[4,5] these standards are not required by the Centers for Medicare & Medicaid Services as of December 2013.[6]

- Vascular access for hemodialysis
  - *Arteriovenous fistula*. This type of access is the preferred access for chronic hemodialysis. It is a surgical anastomosis between an artery and a vein that allows arterial blood to flow through the vein, causing the vein to distend and the vessel to thicken. Maturation of the anastomosis is necessary for 6 weeks to 4 months before use. Infection may result from a break in infection prevention practices, including aseptic technique, bacterial seeding from another part of the body, or poor hygiene and care of the access arm.
  - *Arteriovenous graft*. When a patient requiring chronic access does not have adequate vessels for the creation of an arteriovenous fistula, a biologic, semibiologic, or prosthetic graft may be implanted subcutaneously and used to create an anastomosis between an artery and a vein. Maturation of the anastomosis is necessary and usually takes 3 to 6 weeks. Causes of infection are the same as those of an internal arteriovenous fistula. However, complications resulting from infection may be more severe because of the risk of disintegration of graft materials and subsequent hemorrhage. The average lifespan of a graft is less than that of a fistula.
  - *Temporary vascular access devices*. Subclavian, jugular, or femoral vein catheters may be used for temporary vascular access for hemodialysis. The risk of infection varies according to the type of device, the location (upper or lower extremity, external or internal), method and technique of placement (cut-down, tunneled, percutaneous), and infection prevention practices, including maintenance and access technique. Percutaneously inserted, noncuffed central venous catheters have been associated with the highest rates of bacteremia in the hemodialysis setting.[7,8,9,10,11,12,13,14,15,16]
- Municipal (potable) water used to prepare product water and dialysate for reprocessing of hemodialyzers must be treated to remove chemical, bacterial, or endotoxin contaminants that could be harmful to patients.[2,3,4,5] It should be noted that although potable water is not sterile, chlorine, which is usually added to potable water, impedes bacterial growth. When chlorine is removed from the water, as occurs during treatment of water for hemodialysis, there is little to impede bacterial

growth. Therefore, care must be taken at each step in the water treatment process to minimize the risk of introducing bacteria into the system and prevent treated water from remaining stagnant. Processing potable water to make product water may be created via a centrally plumbed system or portable system. Careful monitoring of the water treatment system by a knowledgeable and well-trained staff is essential for safe hemodialysis and is a condition of participation by the Centers for Medicare and & Medicaid Services.[17,18]

- Continuous renal replacement therapy usually takes place in the intensive care unit setting on patients who are too hemodynamically unstable for hemodialysis, those who are in septic shock and multisystem failure, or those who are oliguric/fluid overloaded but need parenteral nutrition. Hemofiltration requires the rollers of a blood pump to create and release a repetitive negative pressure that pulls the patient's blood from the access and through a hemofilter. Waste products and water (ultrafiltrate) are very slowly removed and collected in an empty sterile bag. Blood access is achieved via a double-lumen central venous catheter. Forms of continuous renal replacement therapy include continuous venovenous hemofiltration, continuous venovenous hemodiafiltration, and slow continuous ultrafiltration.[19]This type of dialysis is not covered in this chapter because the infection risks are primarily related to vascular access, as in hemodialysis, and intrinsic or extrinsic contamination of dialysate. Fluids for continuous renal replacement therapy may be commercially prepackaged or custom compounded in the pharmacy. Intrinsic contamination of dialysate used for continuous renal replacement therapy has been reported.[20]
- Peritoneal dialysis removes toxins, electrolytes, and fluid by diffusion through the peritoneal membrane. Peritoneal dialysis requires placement of a catheter into the abdomen for access and repeated infusion and drainage of dialysate. Several peritoneal dialysis treatment types are available and may require the continuous or intermittent presence of dialysate in the abdominal cavity. Manual method or a machine may be used to perform the dialysate transfer. The peritoneal dialysis machine does not have internal fluid pathways and uses disposable tubing.
- Abdominal access for peritoneal dialysis: Catheter types vary by manufacturer, materials, and design (e.g., Tenckhoff, Palmer, Toronto; Western Hospital, Life-Cath, Valli, and Swan Neck, Missouri). Most peritoneal catheters for chronic peritoneal dialysis are made of silicone and have Dacron cuff(s). The cuffs elicit tissue ingrowth, which in turn stabilizes the catheter and provides a barrier against microorganisms and fluid. Catheters may be inserted percutaneously, laparoscopically, or surgically. The Tenckhoff catheter is the most commonly used catheter in the United States.

Background

Hemodialysis was first performed in 1943 as an intervention while patients recovered from acute renal failure. It was not until the 1960s that hemodialysis became available for patients with chronic kidney failure, but its use immediately raised the issues of capacity and cost. In 1972, Public Law 92-603, section 2991, amended the Social Security Act, Title XVIII, to make end-stage renal disease (ESRD) a Medicare-covered disability for patients who qualified for Social Security.[21]Four years later, the Department of Health Education and Welfare published its first conditions of coverage for ESRD. These were updated in 1988 to cover reuse of hemodialyzers by the Health Care Financing Administration (HCFA), which took over the coordination of Medicare and Medicaid services in 1977. In 2001, HCFA was renamed Centers for Medicare & Medicaid Services (CMS). Proposed changes to Medicare coverage for ESRD were published in January 2005 and the final rule in October 2008.[17]A new bundled payment system for dialysis patients that is directed at lowering complications as well as costs was

implemented in January 2011 by CMS. The final rule includes provisions for the ESRD quality incentive program (QIP), under which payments to dialysis facilities will be reduced if they do not achieve a high enough total performance score based on their performance on measures that assess the quality of dialysis care. Measures for payment year 2014 include monitoring the type of vascular access and thus encourage the use of arteriovenous fistulae and discourage the use of catheters. This QIP also requires dialysis facilities to report dialysis infection events to the Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network (NHSN) in 2014.[22]

Minimum standards that dialysis centers must meet in order to be certified under the Medicare program can be found on the CMS website (see Supplemental Resources). By incorporation, all Medicare-eligible ESRD facilities must demonstrate that they follow standard infection prevention precautions, including those published by the CDC.[7,8] The standards focus on consistency of outcomes regardless of provider.

They take into account increased complexity of water treatment systems, changes in hemodialysis equipment, use of dialysis technicians to provide care, and the importance of evidence-based practices, including those related to infection prevention. Incorporated infection prevention requirements apply to both in-center and home dialysis programs. Compliance with infection prevention conditions is surveyed under Tag Numbers V110 to V148 by observation of care delivery, interviews, and review of medical records, facility logs, policies and procedures, and quality assessment and performance improvement (QAPI) documents.[18] Standardized surveyor tools are available online (see Supplemental Resources).

Since the onset of the prospective payment system in January 2011, the number of new dialysis patients decreased. By treatment modality, new patients starting hemodialysis decreased for the first time in 30 years while the number of new patients on peritoneal dialysis grew. This change may be due to incentives in the new payment system that favors peritoneal dialysis.[1] Between 1991 and 2011, the point prevalence of patients receiving dialysis treatment rose from approximately 145,000 to 430,273.[1,23]

Despite Medicare support of home dialysis, the point prevalence of patients undergoing home hemodialysis continues to increase very slowly and remains low, with only 5,535 patients undergoing home hemodialysis in the United States in 2011.[1]

The increase in patients requiring hemodialysis has resulted in an increase in chronic hemodialysis centers. For example, in 1991, 2,046 hemodialysis centers were licensed by the HCFA, whereas in 2006, 5,067 centers were licensed by CMS and 6,009 in 2011.[1,24] Two large hemodialysis chains, Fresenius Medical Care, which acquired Renal Care Group in 2005, and DaVita, which acquired Gambro Health Care in 2006, owned almost 60 percent (3,576/6,009) of the dialysis units in the United States in 2011.[1] In its 2013 Annual Data Report, the U.S. Renal System reported that costs reached $24.3 billion for hemodialysis and $1.5 billion for peritoneal dialysis in the United States in 2011.[1] Some hemodialysis units have adjusted to the increase in patients by running more shifts of patients and staggering staff work shifts to accommodate workload. Heavily populated centers may run a 6-day schedule of four or five shifts of patients with only 3 to 4 hours of nonpatient treatment hours to perform routine maintenance procedures. Patients are usually assigned to a Monday, Wednesday, Friday or a Tuesday, Thursday, Saturday schedule.

Most patients undergoing dialysis are already at risk for certain types of infections resulting from underlying diseases or conditions (e.g., diabetes, hypertension, cardiovascular disease, immunosuppressive therapy, and critical illness). Dialysis also increases the patient's risk of infection because direct access into normally sterile areas, the circulatory system or peritoneal cavity, is required.

Most common types of dialysis-associated infections include access site infection, bacteremia, and peritonitis. Less common are infections with bloodborne pathogens. In addition to infections, dialysis patients may be at risk for certain adverse reactions that, although not infectious in origin, may be difficult to distinguish from infections. These include pyrogenic, allergic, and chemical reactions, such as dialysis dementia, fluoride intoxication, and chloramine exposure that may be as life threatening as infections. Infections and adverse reactions may be the result of inadequate dialysis systems or procedures, breaks in established procedures, intrinsic contamination of any component of the dialysis system, lack of monitoring for known contaminants, reprocessing failure, or inadequately trained or unknowledgeable staff.

Risk of infection or adverse reactions in the dialysis unit can be reduced by:

- Strict adherence to aseptic technique during all dialysis procedures;
- Strict adherence to procedures for use, disinfection, and maintenance of equipment;
- Knowledgeable, well-trained staff that understand the implications of deviating from established procedures;
- Careful monitoring of all procedures in which bacterial or chemical contamination can occur;
- An effective patient education program that includes teaching patients and their families their role in the prevention of dialysis-associated complications, including health maintenance and prevention of dialysis-associated infections; and
- Routine monitoring and follow-up of patients undergoing dialysis, including an active infection surveillance and prevention program.

This chapter contains basic information on hemodialysis and peritoneal dialysis and provides recommendations for reducing patient risk. Elements of a centrally plumbed water system, a single-pass hemodialysis machine, and monitoring requirements for hemodialysis are discussed. In addition, basic infection prevention approaches to potential outbreak situations and a list of potential U.S. and international dialysis-associated resources are provided.

Hemodialysis

SELECTION AND MAINTENANCE OF VASCULAR ACCESS FOR HEMODIALYSIS

The risk of infection related to circulatory access for hemodialysis varies with the type of vascular access used. There is a sevenfold greater risk for bacteremia in patients with a dialysis catheter than in those with a primary arteriovenous (AV) fistula.[15] The National Kidney Foundation—Kidney Dialysis Outcomes Quality Initiative (KDOQI)[16] and the CDC[8] recommend an AV fistula be created and used for long-term hemodialysis treatment because of the lower incidence of infection and set a fistula creation target of 65 percent by 2009. If an AV fistula cannot be established, an AV graft is the next preferred type of access. Because of infection risk, creation of the fistula in the upper arm is preferred over the thigh. For acute hemodialysis, where access for less than 3 weeks' duration is anticipated, vascular access may be obtained using a noncuffed or cuffed catheter. However, if a catheter must be used for access for longer than 3 weeks, a tunneled, cuffed venous catheter is recommended.[8,16] KDOQI and CDC guidelines state that the preferred insertion site is the right internal jugular, and subclavian access should be used only when jugular options are not available and in patients who are not anticipated to

need permanent vascular access. This is because of a greater incidence of central venous thrombosis and stenosis when the subclavian is used. The CDC also recommends that the patients with advanced kidney disease also not have subclavian catheters used in order to preserve future access sites. The Fistula First Program[25] goes even further and recommends that effort to preserve vascular access be started as soon as possible in patients with evidence of kidney disease. In addition, tunneled cuffed catheters should not be placed on the same side as a maturing AV access if possible. Femoral catheters should be placed only in bed-bound patients only with good exit site care and should be left in place for no more than 5 days because of associated infection rates.[15]

Use of silver-impregnated cuffs or central venous catheters (CVCs) with an external antimicrobial or antiseptic coat may reduce the incidence of central venous catheter-associated sepsis; however, further research in the hemodialysis setting is needed. Catheters should be inserted using maximal sterile Barrier Precautions (mask, sterile gloves, long-sleeve sterile gown, large sterile sheet or drape) following practices outlined by the CDC.[8]

Skin colonization with *Staphylococcus aureus* at the access site has been significantly associated with *S. aureus* access site infections.[26,27] Persistence of *S. aureus* after skin preparation has been shown to be significantly higher in patients with poor hygiene.[26] Therefore, the importance of personal hygiene and its possible relation to access site infections should be emphasized. KDOQI recommends that all patients be taught to wash their access site with soap and water daily and before hemodialysis. Patients should also be instructed to ensure that all staff accessing the access site are preparing the skin appropriately prior to cannulation and in the proper way plus wearing a mask for all access connections.[16] In addition to care of the access site, patients should be taught to recognize signs and symptoms of infection (e.g., fever, chills, and pain, redness, or drainage around the access site). To prevent seeding of the access site by microorganisms, remote sites of infection also should be identified and effectively treated as quickly as possible. Patients should be instructed to report any signs of infection, either at the access site or remote, immediately.

Kaplowitz et al.[28] reported that sterile preparation of the skin over the fistula site (creation of sterile field, use of sterile barriers and gloves) is no more effective in preventing infection than clean technique (clean barriers and gloves with strict attention to aseptic technique). However, a higher rate of infection has been observed when new or inexperienced staff manipulates a patient's vascular access.[29] Because of its broad spectrum of activity, a 2 percent chlorhexidine gluconate (CHG) is the antiseptic of choice. If used, povidone-iodine solution (applied for two to three minutes) and/or 70 percent alcohol (applied in rubbing motion for one minute) should then be applied in an outward circular motion to selected needle insertion site and allowed to dry before cannulation.[16] Meticulous attention to aseptic technique should be used, and the insertion site should not be palpated once the site has been prepared.

When CVCs are used for vascular access, KDOQI notes that it is considered standard practice to clean the exit site and redress the site for each dialysis treatment, but defers to CDC guidelines regarding choice of gauze or transparent dressing unless the insertion site is oozing, in which case gauze should be used.[16] In contrast, CDC guidelines indicate that the dressing should be replaced when it becomes damp, loosened, or soiled or when inspection of the site is necessary.[8] The CDC also states that gauze dressings should be replaced every 2 days and transparent dressings at least every 7 days on short-term CVCs placed in adults and no more than once a week on tunneled or implanted CVC sites until

the insertion site has healed. The CDC notes that the choice of dressing is a matter of preference, but if the insertion site is oozing, gauze is preferred.[8] Because of its broad spectrum of activity, a > 0.5 percent CHG preparation with alcohol is the antiseptic of choice. However, CHG products currently available are not compatible with all dialysis catheters; therefore, the catheter manufacturer should be consulted regarding compatibility. If chlorhexidine cannot be used, KDOQI recommends use of povidone-iodine. Application of povidone-iodine ointment has been shown to decrease the incidence of subclavian-associated sepsis in the hemodialysis setting,[15] but its use may make transparent dressings less occlusive. CDC guidelines also recommend use of povidone-iodine ointment or bacitracin/gramicidin/polymyxin B ointment (not currently available in the U.S.) at the catheter exit site of hemodialysis patients if the ointment does not interact with the material of the hemodialysis catheter.[8] All personnel involved in the maintenance of intravascular catheters should receive education in appropriate infection control measures and be periodically assessed in knowledge of and adherence to the guidelines.[8]

In addition to strict aseptic technique, including hand hygiene and use of clean gloves, KDOQI recommends that the patient and staff members wear masks for all access connections. Tag number V147 of the 2008 interpretive guidance to surveyors notes that dialysis staff should be following this recommendation. Using the 2000 National Kidney Foundation (NKF)-KDOQI recommendations as his reference, Beathard was able to demonstrate a fourfold decrease in the rate of central line-associated bloodstream infections (CLABSIs) in hemodialysis patients by individually wrapping the catheter hubs with gauze soaked in povidone-iodine for 5 minutes prior to removal of the caps, having the nurse and patient wear masks, donning a fresh pair of gloves for cap removal, wiping the surface that had been covered with a cap with a povidone-iodine pledget, and immediately connecting the catheter hubs at connection.[30] The 2006 KDOQI recommendations incorporate this study as evidence for keeping its original 2000 recommendation.[16,29]

Patients should be instructed to keep CVC dressings clean and dry. They, or their caregivers, should also be instructed in the proper way to care for the site and replace the dressing should it become compromised. Patients should be instructed not to submerge their catheter or catheter site in water. Patients may shower if the catheter and insertion site can be covered with an impermeable dressing.[8] Emphasis should be placed on early recognition of possible signs of infection (tenderness, redness, or drainage around the insertion site) and the principles of asepsis when accessing or caring for temporary vascular accesses.[8,16,29]

KDOQI notes that infections of primary AV fistulas are rare and should be treated as a subacute endocarditis with 6 weeks of antibiotic therapy. If septic emboli develop fistula, take down may be warranted. Infection of AV grafts usually requires both antibiotic therapy and surgical intervention. Treatment of CVC infection is often dependent on the nature of the infection and should follow current practice guidelines related to care and maintenance of CVCs.[16,29]

WATER TREATMENT FOR HEMODIALYSIS

The purity of water used for hemodialysis, reuse, or concentrate preparation is critical. In order to be eligible for Medicare reimbursement, dialysis units must meet the Association for the Advancement of Medical Instrumentation (AAMI) standards for water purity.[2,3,17] Most hemodialysis centers have water treatment systems that consist of a water softener, carbon filters, particulate filters, reverse osmosis

and/or deionizers, and filters and ultrafilters, with or without ultraviolet (UV) light. Systems should be designed to remove the anticipated chemical and biologic impurities found in the potable water in the location where they are installed.[2,3] Infection preventionists (IPs) should be familiar with the purity of local potable water, the following components of their facility's water treatment system, and should understand potential problems. As of October 2013 in the United States, "water and equipment used for dialysis meets the water and dialysate quality standards and equipment requirements found in the Association for the Advancement of Medical Instrumentation (AAMI) publication, 'Dialysate for hemodialysis,' ANSI/AAMI RD52: 2004."[31]

Backflow Prevention

A water main break, major supply pipe break, or unexpected high demand can reduce water pressure in the water distribution system. If there is reduced water pressure, water from the ground, storage tanks, or other sources connected to that supply line can backflow into the water system and contaminate it. A break tank or reduced pressure zone valve eliminates risk of backflow of removed chemicals into the public water system and prevents chemicals from entering the dialysis water system if the system fails.

Water Softener

Water softeners exchange calcium and magnesium ions in incoming water for sodium ions. When sodium is no longer available to be exchanged, the water softener must be regenerated. Permanent softeners are regenerated at the point of use with concentrated sodium chloride solution (brine tank). Regeneration should not occur during hemodialysis operation because this may result in unacceptably high sodium levels in effluent, which may not be removed by further treatment of water and could result in hypernatremia. For this reason, it is recommended that water softeners have automated controls that prevent the flow of water during regeneration. Portable softeners may be provided by a vendor and exchanged for a new softener when they become depleted. The vendor regenerates the softeners at a central facility and may reuse them at the same or different dialysis facilities. Bacterial contamination of portable exchange softeners has been reported.

Carbon Filter

Carbon filters remove chlorine, chloramine, and organic material from the municipal water supply. Failure to remove free chlorine and chloramine can degrade some reverse osmosis membranes, which can cause lysis of red blood cells. Carbon filters are prone to bacterial contamination because of their porosity and affinity for organics. Because of the risk of cross-contamination and inadequate disinfection, granular-activated carbon should be used and replaced, not regenerated, when carbon filters become exhausted. Because the temperature and pH of incoming water affects the capacity of carbon beds to remove free chlorine and chloramine, water treatment systems for hemodialysis should warm incoming water, if necessary, and have at least two carbon filters in series. Sample ports should be located after each tank, and chloramine testing should be conducted at least every 4 hours while patients are undergoing hemodialysis. The system should be operating for at least 15 minutes before testing is performed. Testing should be performed after the first carbon tank. When it is time to change carbon tanks, it is usual practice to move the second tank into the primary or "worker" position and the new tank into the secondary or "polisher" position.

Particulate (Sediment) Filters

Particulate filters are used to remove sediment from water that could damage or clog the water treatment system. The use of opaque filter housings helps prevent growth of algae in the filter. Bacterial

growth can occur on the filter and can lead to subsequent bacteremia and/or pyrogenic reactions. Particulate filters should be monitored for pressure drops across the filter. Filters should be replaced or disinfected according to the manufacturer's recommendations; if a disinfection method is used, ensure it is compatible with the hemodialysis water system.

Reverse Osmosis

Reverse osmosis (RO) uses osmotic and hydrostatic pressures over semipermeable membranes to remove ions and organics. In theory, RO is capable of removing 90 to 99 percent of electrolytes and all bacteria and endotoxin. The quality of effluent water from an RO system depends on the quality of water going in (softened, carbon, and particulate filtered) and the integrity of the semipermeable membrane. Important measures of RO performance are percentage of rejection and product water recovery. Reasons for decreases in percentage of rejection include bacterial or chlorine-related degradation of the membrane, fouling of the membrane, and leaks. Cleaning and restoration of semipermeable membranes should be done according to manufacturers' recommendations.

Deionizers

Deionizers contain resin beds, which remove cations and anions by binding them to resin and releasing hydrogen and hydroxyl ions, respectively. Deionizers do not remove bacteria or endotoxin, and resin beds may contribute to substantial bacterial growth. Deionizers should be suspected of producing water that may contain high numbers of bacteria or endotoxin, even if preceded by RO. Because deionizers may produce effluent with carcinogenic nitrosamines unless preceded by carbon absorption, deionizers must always be preceded upstream by carbon filters. Exceeding flow rates or water volume recommended by the manufacturer can result in water that does not meet the AAMI standards for water quality and has been implicated in patient deaths.[32] Deionizers are rarely used as the main water treatment to remove ions in the United States. Instead, they are used as a backup to RO. Dialysis water treatment systems that utilize deionizers are required to have a temperature-compensated resistivity monitor that audibly and visually alarms at a resistivity of less than 1 megohm-cm following the deionizers. In addition, if the deionizing system is the last process in the water treatment system, it must be followed by an ultrafilter or other bacteria and endotoxin-reducing device.

Ultraviolet Light

Dialysis centers may use UV lights to reduce microbial contamination. However, care must be taken as UV irradiation may be ineffective if the radiant energy decreases below effective levels or the light cannot reach the microorganism and it does not remove endotoxin.

Ultrafilters

Dialysis centers use ultrafilters, with or without UV lights, to remove bacteria and for endotoxin removal. The ultrafilter should be the last component of the water processing system before the distribution loop. Depending on the quality of supply water, ultrafilters may also be placed before the RO. Because no system should be considered 100 percent effective at removing bacteria or endotoxin, the use of ultrafilters does not eliminate the need for monitoring of bacterial and/or endotoxin contamination.

WATER DISTRIBUTION AND STORAGE SYSTEMS

Water distribution systems are usually constructed of plastic pipes because the use of metal pipes could contaminate the treated water with elements such as copper, lead, or zinc. The system should be configured as a continuous loop, with no dead ends or unused branches to the piping system, because

these stagnant areas may serve as a source of bacterial contamination for the rest of the water system. There should be a constant flow of water through all distribution piping, and a minimum flow velocity of 1.5 feet per second (ft/sec) should be maintained at the distal end of a direct system at peak demand and 3 ft/sec in the distal portion of the loop in an indirect feed system. The minimum number of elbows and T-joints should be used. Outlets should be at the highest point of the system to allow adequate contact of all parts of the distribution system with germicide during disinfection. Only a plumber who understands the medical implications of plumbing errors should install or modify the dialysis water distribution system.

When possible, storage tanks should not be used because they increase the amount of water and surface area available for bacterial contamination. If a storage tank is used, it should be the smallest tank possible, be designed to have a constant flow with no stagnant areas, have a conical or bowl-shaped base, drain from the bottom, use an airtight lid, and be able to be cleaned, disinfected, and rinsed. All storage tanks should be vented through a hydrophobic 0.2-micron air filter. An ultrafilter or some other form of bacterial control device should be installed distal to the storage tank.

All piping (including water lines between the process's water outlet and the back of the dialysis machines) and storage tanks must be disinfected at intervals adequate to prevent bacterial growth. ANSI/AAMI/ISO 13959:2009 and 11663:2009 standards specify limits of total viable bacteria of 100 colony-forming units per milliliter (cfu/mL) and indicate a need for action if results are in excess of 50 cfu/mL. These standards also specify endotoxin limits of less than 0.25 ELISA units per milliliter (EU/mL) in processed water and less than or equal to 0.5 in dialysate. Endotoxin levels greater than or equal to 0.125 EU/mL in processed water or 0.25 EU/mL in dialysate should prompt action.[2,3,4,5] As stated previously, as of October 1, 2013, dialysis units in the United States are required by CMS to meet 2001 AAMI water standards[2] and 2004 AAMI dialysate standards[3] of less than 200 cfu/mL and an action limit of less than 50 cfu/mL and endotoxin of less than 2 EU/mL and an action limit of less than 1 EU/mL, respectively. Disinfection must be done at least monthly, but more frequent disinfection may be necessary to maintain viable bacteria and endotoxin levels below AAMI standards and is dependent on the quality of the water entering the system and the individual system design. Disinfection schedules should be designed to prevent bacterial growth rather than eliminate it when bacterial contamination over the limit is detected. Chlorine, formaldehyde, peracetic acid, or other commercially available germicides can be used for chemical disinfection of the water distribution system. Hot water (80°C) and ozone generators are also options for water system disinfection if the system is made of heat- or ozone-resistant materials. Chemicals should be used according to the manufacturer's recommendations and must be thoroughly rinsed from the system with treated water before the system is used.

Monitoring of Water That Is Used for Hemodialysis

Initial and routine monitoring of treated water after installation of a water treatment system is the responsibility of the user. The "user" is defined by AAMI as the physician or physician's representative. The user should be knowledgeable of all aspects of the water treatment and distribution system for the facility and have the authority to investigate and act on problems related to the quality of water used for hemodialysis. In the United States, ultimate responsibility for water quality for hemodialysis rests with the medical director of the area.[2,3,17,18]

Water used to prepare dialysate or dilute germicides or reprocess hemodialyzers must meet AAMI standards for hemodialysis water quality.[2,3] Water samples should be obtained from the first and last outlets of the water distribution loop and outlets supplying reuse or bicarbonate mixing tanks, if

applicable. If a problem with the water system is suspected, additional test sites may include before and after the RO membrane, after the storage tank, before and after deionization tanks, and other locations in the water distribution loop. Hemodialysis water purification equipment is categorized as class II medical devices by the U.S. Food and Drug Administration (FDA).

CMS rules are as follows; however, state and local authorities may require more frequent or stringent monitoring. Microbiologic monitoring of treated water and dialysate should be performed at least monthly and more frequently if problems are identified.[2,3] Weekly testing for 1 month should be done when a water distribution system or dialysate system is new or a change has been made in the existing system. Samples should always be taken before disinfection or sanitization of the processed water system or dialysis machines. Bacterial counts and endotoxin levels above the acceptable limit have been associated with pyrogenic reactions and bacteremia. Results should be logged so that trends and the need for corrective action can be identified.

Total viable counts should be obtained using the membrane filter technique (known volume of sample is filtered through a 0.45-μm membrane filter and then transferred to an agar plate) or spread plate (at least 0.5 mL is spread over the surface of an agar plate). Use of a calibrated loop is not permitted because the small amount of water sampled makes this test insensitive.[16] Older AAMI standards indicate that the sample should be inoculated onto tryptic soy agar within 1 to 2 hours of collection, or the sample should be refrigerated and processed within 24 hours. Culture plates should be incubated at 35°C for 48 hours before colonies are counted. The 2009 standards provide revised instructions for plating and incubation to improve recovery of viable bacteria. They indicate that samples should be plated on tryptone glucose extract agar or Reasoner's Agar No. 2 at 17°C to 23°C for 7 days. Dialysis centers should verify that the updated procedure is being followed by the microbiology laboratory performing cultures and request a preliminary result if the colony count is near or greater than 50 cfu/mL at any time during the incubation period. Identification of organisms may be necessary to link high counts to cases of bacteremia or pyrogenic reactions but is not routinely performed unless counts are repeatedly above the action limit or linked to cases. Best practice is to ensure viable bacterial counts in dialysate or water used to perform dialysis or to reprocess hemodialyzers does not exceed 100 cfu/mL, although the requirement in the United States is less than 200 cfu/mL. However, if the action level of 50 cfu/mL, is reached in product water, corrective measures should be taken promptly to reduce the levels back below 50 cfu/mL.

Endotoxin testing may be done by a contract laboratory or using a commercially available test kit. Most commercial laboratories performing endotoxin testing have adopted the 2009 AAMI standards and will alert dialysis units if endotoxin in product water is greater than or equal to 0.125 EU/mL in processed water or 0.25 EU/mL in dialysate.

Chemical monitoring of treated water should be performed at least yearly if RO or deionizers are used and more often if other treatment methods are used. It should be noted that this is the minimum frequency of testing, and more frequent testing may be indicated based on potable water entering the system, design of the system, modifications to the system, or occurrence of symptoms that could be associated with chemical contamination of the water system. Chemical contaminants have been associated with severe illness and/or death. Maximum allowable chemical contamination levels as determined by AAMI must not be exceeded, as shown in Table 39-1.[2,3] AAMI standards require testing for chloramines after water exits the first carbon filter at least once every 4 hours.

Table 39-1 Chemical Contamination Levels

Chemical	Level
Calcium	2 mg/L (0.1 mEq/L)
Magnesium	4 mg/L (0.3 mEq/L)
Sodium	70 mg/L (3.0 mEq/L)
Potassium	8 mg/L (0.2 mEq/L)
Fluoride	0.2 mg/L
Chlorine (free)	0.5 mg/L
Chloramines	0.10 mg/L
Nitrate (N)	2 mg/L
Sulfate	100 mg/L
Copper, barium, zinc	Each 0.1 mg/L
Aluminum	0.01 mg/L
Antimony	0.006 mg/L
Beryllium	0.0004 mg/L
Arsenic, lead, silver	Each 0.005 mg/L
Cadmium	0.001 mg/L
Chromium	0.014 mg/L
Selenium	0.09 mg/L
Mercury	0.0002 mg/L
Thallium	0.002 mg/L

Implications of Inadequate Treatment or Distribution of Water

Chemical and bacterial contamination of water used for dialysis has been associated with adverse events in patients and can be mistaken as signs of infection.[2,3,17,18]

- Aluminum: Associated with anemia, bone disease, and neurological deterioration; can lead to a progressive syndrome of neurologic deterioration and encephalopathy known as dialysis dementia.
- Chloramines (combined chlorines): Associated with hemolysis, hemolytic anemia, and methemoglobinemia.
- Fluoride: Associated with bone disease, pruritus, chest pain, nausea, vomiting, and cardiac arrest due to ventricular fibrillation.
- Copper: Associated with chills, nausea, vomiting, and headaches as well as anemia, liver damage, and fatal hemolysis.
- Zinc: Associated with nausea, vomiting, fever, and anemia.
- Nitrate: Associated with methemoglobinemia, cyanosis, hypotension, and nausea.

- Sulfate: Associated with nausea, vomiting, and metabolic acidosis.
- Calcium or magnesium: Have resulted in a syndrome characterized by nausea, vomiting, muscular weakness, skin flushing, and hypertension or hypotension.
- Sodium: Can lead to hypernatremia, increased thirst, and excess water intake.
- Gram-negative bacteria: Associated with pyrogenic reactions and bacteremia. Symptoms include shaking chills, fever, hypotension, headaches, myalgias, nausea, and vomiting. Note: If no apparent source of Gram-negative bacteremia is identifiable (e.g., bowel perforation), an investigation into the water treatment system, hemodialyzer reprocessing, and priming/ultrafiltrate waste disposal as possible sources should be initiated.
- Endotoxin: Can acutely activate both humoral and cellular immune response, leading to fever, shaking chills, hypotension, multisystem organ failure, and even death. Long-term exposure may lead to a chronic inflammatory response. Note: Endotoxin-like reactions should prompt investigation into the water treatment system and hemodialyzer reprocessing as possible sources.
- Nontuberculous mycobacteria: Have been associated with disseminated disease, bacteremia, localized abscess, and localized graft infection. Symptoms include fever, malaise, and anorexia. Note: If no apparent source of mycobacteria is identifiable (e.g., infection at a remote site), an investigation into the water treatment system and hemodialyzer reprocessing as possible sources should be initiated.

Dialysate Components and Delivery Systems

Hemodialysis utilizes acetate or bicarbonate concentrates. Because of its high salt molarity, most bacteria cannot grow in acetate concentrate. However, bicarbonate concentrate can support fairly rapid bacterial growth and endotoxin production. Bicarbonate concentrate may be purchased in powder or aqueous forms. If purchased in powder form, it should be mixed with product water that meets AAMI standards as close as possible to the start of hemodialysis.[2,3]

Centers may choose to prepare a batch of bicarbonate concentrate in a mixing tank, in individual jugs, or using an automated mixing process during actual dialysis. Unused bicarbonate should be discarded at the end of the day or at a frequency recommended by the concentrate manufacturer to maintain bacterial and endotoxin levels in dialysate below AAMI standards. Disinfection of mixing tanks should be done in accordance with manufacturer's instructions and occur at intervals adequate to prevent bacterial growth. Disinfection is usually necessary at least daily and, if the germicide must be rinsed with processed water, disinfection should occur before the tank is used so that water, which could contain bacteria, will not be allowed to sit in the system and proliferate overnight. The mixing and disinfection information should be recorded for each batch (cycle) on a dedicated log.

When reusable jugs are used to distribute bicarbonate concentrate, they and associated tubing should be emptied, rinsed with treated water, and inverted to air dry after each treatment. Jugs should be disinfected using a chemical disinfectant that is compatible with dialysis machines. Disinfectants should be used according to the manufacturer's directions. If bleach is used, AAMI recommends a 1:100 dilution of bleach or a bleach solution with 300 ppm to 600 ppm free chlorine with a contact time of about 30 minutes.[3]

Cartridges for automated bicarbonate mixing should be discarded according to the manufacturer's recommendations or, if not specified, at the end of the day.

Dialysate is a combination of treated water and acetate or bicarbonate concentrates.[3]Mixing of treated water and dialysate components can be done in a central proportioning system and then distributed to

individual stations or in individual dialysis machines. All fluid pathways for either mixing-delivery system can be a source of bacterial and endotoxin contamination.

AAMI requires that monthly dialysate samples be collected for bacterial monitoring during or at the termination of dialysis at or beyond the point where the dialysate leaves the hemodialyzer.[2,3] AAMI does not specify the frequency with which dialysate from each dialysis machine should be tested. However, AAMI does state that at least two machines should be tested each month and from enough machines that each machine is tested at least once per year. For units with a large number of dialysis machines, the author suggests that a representative number of machines be sampled on a monthly basis and more frequent or extensive testing be performed if a problem is suspected because of routine sampling results or a cluster of patient infections.

Dialysis Machines

A blood pump, consisting of two or more rollers, is usually necessary to pump the patient's blood through tubing and the hemodialyzer at stable and accurate blood flow rates. If obstruction occurs between the blood outlet of the hemodialyzer and the patient, pressure in the blood compartment of the hemodialyzer may increase enough to rupture the hemodialyzer membrane or cause a disconnection or rupture of tubing. Personnel should always have personal protective equipment (fluid-resistant gown, mask, and eyewear) readily available to prevent their exposure to blood in such an event.

There are three types of fluid pathways in hemodialysis machines: recirculating, recirculating single-pass, and single-pass machines. Recirculating machines circulate dialysate repeatedly through the hemodialyzer during dialysis, whereas recirculating single-pass machines have a reservoir that is partially displaced by a constant flow of fresh dialysate. Single-pass machines discard all dialysate through the drain. Virtually all hemodialysis machines in the United States are single-pass.

Recirculating systems permit nutrient-rich waste products from the patient to be used as nutrients for microorganisms and therefore may result in increased levels of bacteria during the dialysis treatment. All internal fluid pathways of recirculating or recirculating single-pass dialysis machines should be disinfected immediately prior to first use and after each patient use. If a blood leak occurs in a recirculating or recirculating single-pass machine, the disinfection procedures used for the machine to control bacterial infection are considered sufficient to reduce blood contamination below infectious levels.

In contrast, single-pass machines provide a constant flow of dialysate, which passes through the dialysate compartment and is discarded. Contamination of single-pass systems is usually related to the quality of treated water or other dialysate components going into the machine and the adequacy of cleaning and disinfection procedures. Therefore single-pass delivery systems are preferred. In a single-pass machine, the internal fluid pathways that supply dialysis fluid to the dialyzer are not subject to contamination with blood. If a blood leak occurs in a single-pass machine, it is not necessary to disinfect the internal fluid pathways because even if the fluid pathways that exhaust dialysate became contaminated with blood, it would be unlikely that this blood contamination could reach the patient.

External surfaces of the hemodialysis machine should be cleaned and disinfected after each patient. If fluid (water or dialysate) has been allowed to sit in the machine overnight, all internal fluid pathways of single-pass dialysis machines should be disinfected immediately prior to first use of the day and at the frequency recommended by the manufacturer of the machine. Pipes and tubing of incoming water (batch system) or dialysate (proportioning system) as well as the internal dialysate and dialysate concentrate pathways must be disinfected. This may be achieved using heat (80°C [176°F]), a bleach solution, formaldehyde, peracetic acid, or glutaraldehyde according to the manufacturer's directions.

Waste from the dialysis machine must not be allowed to back-flow into the machine. This is most often accomplished by allowing an air gap between the drain hose and the drain to prevent back-siphon. In addition, state and local authorities should be consulted for plumbing requirements.

BEDSIDE OR PORTABLE HEMODIALYSIS

It is not unusual for hospitals to provide bedside hemodialysis utilizing either their own hemodialysis staff or a contract service. It is imperative that personnel performing bedside hemodialysis understand how the portable water treatment system functions and the monitoring requirements. Bedside dialysis must be done utilizing treated water and dialysate that meets AAMI standards.[2] In order to provide treated water, a portable water treatment system is used and generally consists of at least a sediment filter, carbon filter(s), and portable RO with appropriate monitors (conductivity, total dissolved solids, pressure gauges, etc.). Most RO systems require the use of tempered water, which can be the source of excessive microbial contamination and fouling of the RO membrane. Tempering of water should be done as close to the point of use as possible. If blending valves are used, frequent water flow through the valve is necessary to prevent bacterial growth. Treated water must be tested for chloramines prior to the start of hemodialysis, and at least every 4 hours for a treatment extending more than 4 hours. The quality of the product water from portable treatment systems must meet all AAMI standards for treated water, including monitoring frequency.

It is not unusual for the source of water for bedside hemodialysis to be a hand-washing sink or for a portable machine to drain into a sink or commode. If this is done, it is important to provide an alternative for hand hygiene, such as an alcohol-based hand rub. It is important to maintain an air gap by not allowing the discharge tubing to touch the water in either location. This can be done by securing the tubing to the toilet lid or faucet handle. If provision of hemodialysis at the bedside is anticipated in a newly constructed area or an area that is undergoing renovation, inclusion of a well-designed dialysis sink capable of providing tempered water and a closeable dialysis drain designed to hold discharge tubes over a drain to avoid contact and splatter should be considered. Care should be taken to ensure that the tempered water does not stagnate between uses or microbial growth will occur.

WASTE BUCKETS AND BLOOD TUBING

Clustered bacteremias with Gram-negative bacillus and *Enterococcus casseliflavus*resulting from contamination of dialysis blood tubing with priming waste during hemodialyzer setup have been reported when using waste buckets.[33] In addition, clusters of bacteremias in hemodialysis centers have been reported at facilities using some hemodialysis machines.[34,35] These reports have attributed patient infections to incompetent one-way valves or contamination of dialysis lines directly or indirectly from microbial growth in the WHO.

Control measures when using priming waste buckets include:

- Consider using one-use disposable containers for priming. Many centers use disposable urinals for this purpose.
- Do not attach the venous tubing directly to the waste container during hemodialyzer priming.
- Emphasize glove change and hand washing/hand hygiene after contact with priming waste.
- Decontaminate reusable priming waste containers after each patient.

Control measures when using the WHO include:

- Daily testing of the competency of WHO valves to determine whether drain reflux is occurring as recommended by the manufacturer.
- Educate staff about the design, operation, maintenance, and potential hazards associated with using the WHO.
- During reconfiguration of blood lines for saline recirculation, the arterial line connector (connector that comes in direct contact with the WHO) should not be removed from the WHO. Instead, the arterial line should be carefully unscrewed from the arterial line connector without touching the end that has been in contact with the WHO.
- Disinfect the WHO nightly by directly instilling 5.25 percent sodium hypochlorite to prevent microbial overgrowth around the rim of the port that is shielded from disinfectant flowing through the rinse arm.

HEMODIALYZERS

The type of hemodialyzer used varies from center to center. Membranes may be composed of cellulose treated by cuprammonium process (cuprophane) with or without various agents (e.g., cellulose acetate) or may be synthetic (e.g., polysulfone, polycarbonate, polyacrylonitrile, polymethylmethacrylate). Synthetic membranes are thought to be more "biocompatible" because they induce less leukopenia or complement activation. Membranes vary in several ways, including pore size and blood leak rate. Blood and dialysis compartments in all types of the hemodialyzer configurations are completely separated by the semipermeable membrane. Hollow-fiber hemodialyzers are the most commonly used configuration of hemodialyzer. In hollow-fiber hemodialyzers, a potting material is used to hold the membranes in place.

Conventional and high-efficiency dialysis usually utilizes cellulose membranes, whereas high-flux dialysis usually utilizes synthetic membranes. The CDC reported that, in 1990, dialysis centers using high-flux dialyzer membranes were more likely to report pyrogenic reactions, particularly when hemodialyzers were reused, when compared with centers using only conventional hemodialyzer membranes.[36] However, no association was noted between high-flux dialysis and septicemia. A prospective comparison of patients treated with high-flux or conventional hemodialysis found no difference in the incidence of pyrogenic reactions.[37]

Adverse effects (first-use syndrome) have been associated with use of new hemodialyzers and include back pain, chest pain, hypotension, nausea and vomiting, itching, and cramps.[38] Reprocessing of hemodialyzers before first use has been shown to reduce the incidence of first-use syndrome for some patients. The etiology of first-use syndrome is not completely understood. However, this phenomenon has become less prevalent, and current thought is that newer methods of processing new hemodialyzers, such as gamma irradiation instead of ethylene oxide during manufacturing as well as manufacturer recommendations for priming new hemodialyzers, have resulted in this reduction.

Reprocessing and Reuse of Hemodialyzers

IPs should be familiar with the basic concepts of hemodialyzer reuse and the reuse program in their own facility. Despite hemodialyzers being labeled for single use, reprocessing and reuse of them has become common practice in the United States because of improved biocompatibility when using reprocessed hemodialyzers and due to significant cost savings. In 2000, 80 percent of chronic hemodialysis centers reported reuse of hemodialyzers.[23] CMS has incorporated AAMI RD47:2002/A1:2003 into the 2008 Conditions for Coverage of ESRD.[39] It should be noted that since that time, AAMI has revised this standard, which is now available as RD47:2008.[40] In 2002, Fresenius

Medical Care, the largest provider of dialysis care in the United States, ceased reuse at all of its facilities. The current percentage of centers performing reuse is unknown because the CDC no longer surveys units to determine the prevalence of reuse. Risk and benefits of reuse continue to be debated.[41]

All personnel performing reprocessing procedures should receive initial education and training in a well-planned and documented training course before beginning reprocessing. Personnel should not be allowed to perform reprocessing until they have completed the training course. The training course should emphasize the potential risks to patients and staff of not following established procedures and should give personnel being trained adequate opportunity to perform reprocessing procedures under the supervision of a knowledgeable instructor. The training course should include all elements recommended by the AAMI and required by regulatory agencies, such as the Occupational Safety and Health Administration (OSHA). Competency at performing reprocessing procedures should be assessed initially and on a regular basis to ensure continued adherence with recommended and required practices.

Continuous quality improvement activities should include review of reprocessing procedures. When deviations from written procedures are observed, retraining of personnel should be performed. Because of the risk to themselves and to patients associated with reprocessing, personnel who are repeatedly observed not to follow established reprocessing procedures, even after retraining, should not be allowed to reprocess hemodialyzers. Patients who are known to be positive for Hepatitis B surface antigen (HBsAg) should be excluded from reprocessing programs because of the risk of transmission to susceptible reuse personnel.

A system should be in place to ensure that hemodialyzers are adequately labeled and used for one patient only. Despite the development and enforcement of reprocessing standards, there continue to be risks associated with reprocessing. These include a decline in the functioning or integrity of the semipermeable membrane, infusion of sterilant into a patient, infection, pyrogenic reaction, and other adverse reaction. Used hemodialyzers should be handled in a way that conforms with standard precautions until the dialyzer has been disinfected internally and externally. The practice of placing multiple used dialyzers in a bin or sink prior to reuse is not acceptable. Each hemodialyzer should be contained and individually reprocessed in a manner that prevents cross-transmission. Many centers complete this by sealing the used dialyzer in a bag during transport and holding for reprocessing. If a dialyzer cannot be reprocessed within 2 hours, it should be refrigerated and not allowed to freeze. Strict record keeping of temperatures is required by CMS.

To ensure adequate functioning and integrity of the semipermeable membrane, performance measurements and a membrane integrity test, such as an air pressure leak test, should be performed after each use.[42] A 10 percent loss of in vitro clearance is acceptable. In hollow-fiber hemodialyzers, a total cell volume of at least 80 percent of the original total cell volume is considered acceptable and may be measured in place of in vitro clearance. If the expected weight loss is not achieved with a reprocessed hemodialyzer, the reprocessing method should be reevaluated. Although reuse is generally considered safe and cost-effective, pyrogenic reactions and bacteremia have occurred.[42,43,44,45,46,47,48]

These problems have been associated with improper or inadequate disinfection procedures and inadequate potency of the solution used to disinfect the hemodialyzer. Reprocessing and use of high-flux membranes have been associated with higher reported frequency of pyrogenic reactions, regardless of the germicide used.[36]

The hemodialyzer should be rinsed and cleaned and pass performance tests before disinfection with a germicide. If the headers (end caps) of the hemodialyzer are removed during the cleaning process, headers and O-rings should be immersed in disinfectant before reassembly of the hemodiaylzers.[46]

When Gram-negative bacteremia is identified, the reprocessed hemodialyzer should be discarded because it may act as a continuing source of bacteria. If bleach is used as a cleaning agent before reprocessing, it should be used at low concentrations (1 percent), or it will render the membrane as biologically active as a new hemodialyzer. Compatibility of germicides should be clearly established before they are used together to avoid the possibility of chemical reactions and subsequent injury to patients and personnel. Historically, bacterial contaminants of water were thought to consist primarily of Gram-negative organisms. However, nontuberculous mycobacteria are now known to contaminate water and have been linked to infection in the dialysis setting.[47,48]These organisms are much more resistant

to chemical germicides than are Gram-negative organisms. A 4 percent concentration of formaldehyde at room temperature is necessary to kill nontuberculous mycobacteria. In an outbreak in a hemodialysis unit in California, a 2.5 percent Renalin solution did not appear to ensure complete killing of *Mycobacterium chelonae*in high-flux hemodialyzers that were manually reprocessed.[48]Chemical

germicides used for the reprocessing of hemodialyzers should have at least comparable bactericidal activity to a 4 percent concentration of formaldehyde. If formaldehyde is used as the sole germicide, a concentration of at least 4 percent should be used, with a minimum contact time of 24 hours if the hemodialyzer is stored at room temperature (20°C).[47]If other germicides are used, the

manufacturer's instructions should be followed. All reprocessed hemodialyzers should be rinsed and primed according to either manufacturer's directions or a procedure that has been documented to reduce the concentration of germicide to a safe level. The outside of the hemodialyzer should, at minimum, undergo low-level disinfection.

Personnel should be aware of the possibility of rebound (diffusion of germicide from solid components of the hemodialyzer) and the need to perform additional rinsing and testing of the hemodialyzer if there has been a time delay between rinsing or priming and the initiation of the dialysis treatment. The effluent should be tested immediately before use by an accepted method for the germicide used, and the result should be documented. A safety measure that may be helpful is training patients to observe and verify that testing for the absence of germicide has occurred immediately prior to the start of their dialysis. If a reprocessed hemodialyzer is to be taken apart and cultured, samples should be obtained immediately after priming to avoid the effects of rebound and therefore the possibility of false-negative results.[46]

Treated water used to reprocess the hemodialyzers has been implicated as the source of organisms causing bacteremia. Only treated water that meets AAMI standards should be used for rinsing hemodialyzers before infusion of germicide and for preparation of chemical germicides.[16]

The number of times that a hemodialyzer is reprocessed should be documented. If the average number of reprocessing decreases, an investigation of reprocessing procedures should be conducted to determine whether deviations from established procedures or equipment failure are responsible.

Patient Monitoring

The patient's clinical course should be observed and recorded during each dialysis treatment to identify possible complications related to dialysis or hemodialyzer reprocessing. A patient's temperature should be measured and recorded at least before and after each dialysis treatment. Any temperature greater than 37.8°C (100°F) taken orally, chills, or other unexplained symptoms occurring after onset of

hemodialysis should be evaluated for relationship to water treatment, dialysis equipment, and dialysis and reprocessing procedures.

AAMI recommends that a file be kept of all complaints by patients and staff about failures of reprocessed hemodialyzers or possible adverse reactions to reprocessed hemodialyzers. The file should include the results of a comprehensive investigation of the allegations and the corrective actions taken, if any. This file is required by CMS.

Peritoneal Dialysis

Basic components for peritoneal dialysis include abdominal access, sterile dialysate, and a schedule and system for dialysate infusion and removal.[16] This treatment modality offers greater control for patients because treatments can be self-administered in almost any place aseptic practices can be maintained. Exchanges, the process of draining and filling dialysis solution, are usually done via a surgically implanted catheter for about 40 minutes at 4- to 6-hour intervals.

Catheter-associated problems are a leading cause of permanent transfer to hemodialysis in peritoneal dialysis patients. Although the incidence of peritonitis has progressively declined over the last 20 years because of advances in patient education, catheter connectors, and catheter technology, infections continue to be a significant source of morbidity and catheter loss. Risk factors for infection include staphylococcal nasal carriage, young age, lack of compliance with routine procedures (e.g., poor exit site care, breaks in aseptic procedures during connect or disconnect), dialysate leak, exit site skin breakdown or poor healing, trauma to the exit site, or dislodging of the catheter cuff. Most infections are due primarily to catheter placement and maintenance.

Steps to reduce peritoneal dialysis catheter-associated infections include:

- Careful planning of catheter placement: The exit site should be placed to avoid skin folds and the beltline and should anticipate the change in the patient's abdomen following infusion of dialysate. The catheter should be easily accessible to the patient to allow for routine catheter inspection and care and consider the dominate hand (e.g., right-handed or left-handed). A downward directed site in pediatric patients and directing the subcutaneous portion of the catheter downward were associated with lower peritonitis rates.[49,50]
- The International Society for Peritoneal Dialysis (ISPD) advocates use of a double-cuff catheter because of fewer exit site complications and longer survival times than are seen with single-cuff catheters. Catheters should be placed under sterile conditions in an operating room. Prior to surgery, the patient should shower or bathe. Use of one dose of a first-generation cephalosporin is advocated for antibiotic prophylaxis at the time of catheter insertion, especially in centers with high postoperative wound or exit site infections. In order to avoid development of resistant bacteria, Gokal and colleagues recommend that vancomycin not be routinely used as prophylaxis.[51,52] However, 2005 ISPD guidelines/recommendations indicate that each program must carefully weigh the potential benefits of using vancomycin versus the risk of hastening vancomycin-resistant organisms.[53]
- Strict use of aseptic technique in the care of the operative wound and catheter exit site should be observed. Sterile dressings should be applied until the exit site and tract is healed. Because of oozing or leaking from the exit site, a gauze dressing may be preferable to an occlusive transparent dressing until the site is completely healed. The catheter should be immobilized using a dressing or tape during the first 4 to 6 weeks to reduce trauma due to torsion of the catheter and to promote tissue

growth. The patient should be instructed to avoid clothing that would put pressure on the wound or exit site and to protect these areas from external moisture. Baths and showers should not be taken until the site has healed to avoid colonization with waterborne bacteria. The procedure previously promoted by the ISPD indicated that masks should be worn by the patient and care provider and that the preferred antiseptic for catheter care is 2 percent CHG. However, no conclusive studies have been done that definitively indicate one antiseptic over another.[51,52,53] Antiseptics routinely used include CHG and povidone-iodine. Diluted bleach products have also been approved by the FDA as a disinfectant for catheter limbs and connection sites and wound cleanser. Mupirocin cream or ointment has been found to be beneficial in preventing exit site infections when the patient is colonized with *S. aureus*. However, care must be taken to ensure that the catheter is compatible with all products used because cracking of polyurethane surfaces was reported at one center and increasing rates of mupirocin resistance should be considered.[54]

- Exit site care after healing should be performed daily and when the exit site becomes wet or soiled. Exit site dressings are not required for adults but may assist in preventing exit site infections in children.[55,56] An antiseptic, such as 2 percent chlorhexidine gluconate, should be used to keep the exit site clean and decrease resident bacteria around the exit site. Crusts or scabs should never be forcibly removed. The catheter should be immobilized in a way that minimizes the chances of accidental pulling or trauma to the surrounding skin. Powders, lotions, ointments, and so forth that are irritating to the skin should not be used at the exit site. Hydrogen peroxide is drying and should be avoided for routine care.[53] Patients should not allow the catheter or exit site to "sit" in water (i.e., bathtub, hot tub, lakes, or ponds). Controlled studies are necessary to determine the best procedures for exit site care.
- Patients and personnel must be vigilant for early manifestations of catheter-associated infections. Patients should be instructed to contact their healthcare provider as soon as a problem is recognized.

Connection to the patient's abdominal access may be done with a transfer set (manual method), UV light system that exposes the spike and the bag port to UV light before spike insertion (utilizes manual assist to remove and reinsert spike), and Y sets (most commonly used because of lowest risk of infection). Use of disconnect systems, such as the Y connector introduced by Maiorca et al. in 1983 used with a "flush-before-fill" technique instead of a standard spike set, have decreased the incidence of peritonitis in peritoneal patients.[57] When compared with standard spike system patients, lower rates of *Staphylococcus epidermidis* and polymicrobial peritonitis are seen in Y set patients. Aseptic technique should always be used during exchange procedures. If used, machines should be cleaned and disinfected between uses according to the manufacturer's instructions. The use of a mask during connect and disconnect procedures may reduce the risk of infection associated with nasal carriage of *S. aureus*.

Sterile dialysis solutions are commercially available, and most come in polyvinyl bags. They should be inspected for expiration date, cracks, leaks, and particulate matter before use and should be discarded if found. Additives (electrolytes, medication) to dialysate may be necessary and should be added to the dialysate immediately before use. Aseptic technique, including disinfection of vial tops and ports, should be used.

Warming of dialysate is necessary before infusion. Warming should be done using a dry method (warming cabinet, incubator, or heating pad). The manufacturer of the dialysate should be consulted for recommended methods for the product. Procedures for warming dialysate should ensure that heating of the dialysate is even and at physiologic temperatures to avoid patient injury.

Schedule and system for dialysate infusion and removal includes:

- Intermittent peritoneal dialysis (IPD). Treatments are performed several times a week, usually overnight, and may last 8 to 14 hours. IPD usually requires use of a machine (cycler) to heat the dialysate and perform automatic exchanges. The cycler requires disposable tubing and prepared dialysate, which must be set up and connected to the patient's abdominal access following specific procedures. All dialysate is drained from the peritoneal cavity at the termination of the treatment.
- Continuous ambulatory peritoneal dialysis (CAPD). Exchanges of dialysate are made every 4 to 6 hours during the day. A manual or assisted manual method may be used. Patients retain a specific volume of dialysate (dwell) in the peritoneal cavity (usually up to 2 L for adults) at all times.
- Continuous cycling peritoneal dialysis. Exchanges of dialysate are usually done every 2 to 3 hours overnight. A machine (cycler) is required to heat the dialysate and perform automatic exchanges. Patients retain a specific volume of dialysate or dwell in the peritoneal cavity during the day.

There are three types of infections related to peritoneal dialysis: exit site infection (erythema, tenderness, exuberant granulation tissue, or edema of the catheter exit site with purulent or bloody drainage), subcutaneous tunnel infections (erythema, edema, or tenderness of the subcutaneous catheter pathway with purulent drainage or cellulitis), and peritonitis that includes at least two of the following: signs or symptoms of peritonitis (e.g., abdominal pain or fever), cloudy dialysate, dialysate with white blood cell counts greater than 100 cells/mm^{3}and 50 polymorphonuclear leukocytes, and positive culture or Gram stain of the dialysate.

Gram-positive organisms are the most common pathogens isolated from patients with peritoneal dialysis-associated infection.

- Coagulase-negative *Staphylococcus*is the most frequently isolated pathogen from peritoneal dialysis patients with peritonitis followed by *S. aureus*and streptococci.[58,59]
- Exit site infections are most often caused by staphylococci and by *Pseudomonas aeruginosa*.[58]
- Tunnel infections are usually caused by*S. aureus, P. aeruginosa*, and members of the Enterobacteriaceae.[58]

Sources of pathogens include the patient's skin or anterior nares, the dialysate delivery system, as a result of breaks in technique or extrinsic or intrinsic contamination, transmural migration from the gastrointestinal tract, and vaginal leaks.[60,61]Patients are more likely to develop peritonitis after an exit site infection. Bacteremia as a result of peritonitis in CAPD patients is exceedingly rare.[62]

Negative cultures are seen in 4 to 48 percent of reported cases of peritonitis in patients undergoing CAPD and may be due to inadequate culture methods.[58]Optimal culture methods have not been determined but von Graevenitz and Amsterdam recommend the following: only cloudy fluids should be sent for culture; if the sample cannot be processed immediately, it should be stored at 4°C and processed within 6 hours; a minimum of 10 mL should be cultured, using enrichment broth with antiphagocytic and lytic properties, and subcultures of the enrichment broth should be done on, at least, chocolate agar (aerobic) and blood agar plates (anaerobic); media should be incubated for as long as 7 days, and one medium should be incubated at 30°C to detect psychrophilic bacteria; and, if cultures remain negative, mycobacterial and fungal stains and cultures should be initiated.[58]

Patient education and compliance are essential to the prevention of peritoneal dialysis-associated infection. Education on catheter placement before use and continuing education on proper catheter and exit site care should be provided. Patients should be instructed to use the same technique every time that they perform an exchange. Careful and thorough hand washing as well as the difference between clean and sterile should be taught. Patients and their care providers must understand how bacteria can enter the peritoneum. Some patients and family members find demonstration and written material helpful. Patients should be taught to immediately report any sign of infection (e.g., redness or pus around the exit site, swelling, soreness, cloudy effluent, fever). Education should be documented and reinforced during each patient encounter.[51,52,53]

Prevention Of Bloodborne Pathogens In Dialysis Settings

GENERAL RECOMMENDATIONS

Employers are required to perform a hazard assessment to determine when and what personal protective equipment (PPE; fluid-resistant gowns, gloves, masks, and goggles or glasses with solid side shields or face shields) is necessary.[63] Staff members must follow Standard Precautions (formerly Universal Precautions) when exposure to blood or other potentially infectious materials (including peritoneal fluids) is anticipated or likely (also see **105. Minimizing Exposure to Blood and Body Fluids**).[64,65] Times during which exposure is most likely to occur include initiation and termination of dialysis and during reprocessing, cleaning, or disinfection procedures.

PPE should be readily available to dialysis personnel and visitors in appropriate sizes. The use of PPE and hand hygiene must be monitored and enforced.[63] Prompt, thorough cleaning and disinfection of surfaces and equipment that are contaminated with blood or other potentially infectious material should be done using a 1:100 dilution of household bleach, an Environmental Protection Agency (EPA)-approved hospital disinfectant with a tuberculocidal label claim, or EPA-registered disinfectants that are labeled as effective against Hepatitis B virus (HBV) and human immunodeficiency virus (HIV)[66] (also see **31. Cleaning, Disinfection, and Sterilization**; and **107. Environmental Services**).[67] Disposable items contaminated with blood, peritoneal fluid, or other potentially infectious materials should be discarded according to state and federal requirements; definitions of waste may vary from state to state (also see **113. Waste Management**). Personnel exposed to blood or other potentially infectious materials should follow current CDC and Public Health Service recommendations (also see **101. Occupational Exposure to Bloodborne Pathogens**).[64,67]

HEPATITIS IN HEMODIALYSIS

The transmission of HBV and Hepatitis C virus (HCV) in hemodialysis units has been documented. For this reason, infection prevention practices should be reviewed regularly and rigorously followed.[4] The CDC recommends that gloves be placed near each dialysis station. Hand hygiene should be practiced after gloves are removed, between patient contacts, and whenever contamination of hands occurs. Any item that is taken to a dialysis station, including those on top of the machine, should be discarded, or cleaned and disinfected, before being returned to a common area or being used on another patient. Unused medications or supplies (e.g., syringes, alcohol swabs, tape, dressings) should be discarded. There should be clear separation of clean and dirty areas. Common carts, trays, and such should not be used within the treatment area to prepare or distribute patient medications and supplies.

Hepatitis B vaccine is recommended for all susceptible hemodialysis patients and staff.[63,64,67] Because antibody response is poorer in hemodialysis patients than in healthy control subjects, larger vaccine doses or an increased number of doses are required. In addition, vaccine-induced protection is less complete in dialysis patients and necessitates administration of booster doses if antibody levels decline below 10 mIU/mL.

Decreased incidence and prevalence of HBV infection among patients and staff members—coupled with findings that the number of years on dialysis is a major risk factor independently associated with higher rates of HCV among patients—have resulted in revised recommendations on the frequency of routine serologic screening of patients and staff.

Serologic testing for Hepatitis B surface antigen (HBsAg), antibody to core antigen (anti-HBc), antibody to Hepatitis B surface antigen (anti-HBs), antibody to Hepatitis C virus (anti-HCV), and alanine aminotransferase (ALT) should be performed on admission to a hemodialysis unit. Results of Hepatitis B testing should be known before the patient begins dialysis. If results are not known, the patient should be treated as if he or she is HBsAg positive until the results indicate otherwise. Patients who are anti-HBc and anti-HBs positive do not require further Hepatitis B virus-related testing. Patients who are only anti-HBs positive require annual anti-HBs testing and a booster if anti-HBs declines to less than 10 mIU/mL. Patients susceptible to Hepatitis B virus, including those with no response to the vaccine, should be tested monthly for HBsAg. All anti-HCV negative patients should be tested for increased ALT at least monthly and anti-HCV semiannually.

Note: Care should be taken when testing for HBsAg because recent administration of Hepatitis B vaccine may result in positive HBsAg results for 7 to 30 days following vaccination.[68]

Routine testing of staff for HBV is no longer considered necessary because their risk is no greater than that of other healthcare personnel. Routine testing is recommended only to document response to Hepatitis B vaccination. Routine testing of staff members for other bloodborne pathogens is also not recommended.

Separating HBsAg patients by room or area and using a separate dedicated machine is still recommended to reduce transmission of HBV in the dialysis setting because the incidence of HBsAg has been found to be higher in dialysis units that are not following recommendations on the segregation of patients, and those who are HBsAg positive should not be included in dialyzer reuse programs.[67]

Fissell et al.[69] reported that there is no consensus regarding the need to isolate HCV infected patients and dialyze them on dedicated machines to prevent transmission. Investigators have reported that isolation of patients, use of experienced staff, and strict attention to infection prevention practices are associated with decreased rates of infection. However, the decreased risk is thought to be due to strict enforcement of standard procedures that should be used in the dialysis setting. At this time, the CDC and Kidney Disease: Improving Global Outcomes do *not* recommend dedicated machines, patient isolation, or a ban on reuse in hemodialysis patients with HCV infection. Instead, both of these organizations advocate strict adherence to basic dialysis procedures to prevent transmission[4,70]

Hepatitis Delta Virus

Transmission of Hepatitis delta virus (HDV) among hemodialysis patients has been reported, but prevalence in the United States is low.[71] The CDC recommends routine screening for HDV only if there is

a patient who is known to be infected with HDV or there appears to be evidence of transmission in the dialysis unit.[7] Because of high concentrations of HDV in infected patients and the potential for patient-to-patient transmission, it is recommended that patients who are infected with HDV receive dialysis in areas that are separated from all other dialysis patients, including HBsAg-positive patients, and receive dialysis on dedicated machines.

HUMAN IMMUNODEFICIENCY VIRUS IN HEMODIALYSIS

Transmission of HIV from infected patients to other hemodialysis patients or staff members has not been reported in the United States. HIV transmission was reported in Colombia and was associated with common exposure or patient-to-patient transmission.[72] The efficiency of transmission of HIV in the dialysis setting appears low and careful attention to standard precautions and routine precautions that should be followed in all dialysis units (asepsis, disinfection of multiple use equipment, single use of disposables, safe medication practices, etc.) should be effective in preventing transmission if strictly enforced.[7] Patients who are HIV-antibody positive or have acquired immunodeficiency syndrome (AIDS) do not have to be isolated from other patients or receive dialysis on separate machines. Routine screening for HIV antibody is not recommended and, if known, HIV-infected patients may be included in reprocessing programs. Standard Precautions should be followed.[63]

Education And Training Requirements For Dialysis Personnel

All personnel should complete OSHA-required training and be oriented to their job duties before beginning their first assignment.[63,64,65] Orientation, including the course content and a certification of the employee's competence, should be documented. Employees' knowledge should include a thorough understanding of policies and procedures of the facility for patients, employees, and visitors with communicable disease, methods to prevent infections and adverse reactions in dialysis patients, and specific policies and procedures of the facility for prevention of healthcare-associated infections (HAIs) or adverse outcomes (specific to the tasks each employee performs). All personnel should know their roles in the prevention of HAIs and other adverse outcomes. Personnel providing direct patient care should know the symptoms of infection and adverse reactions. They should also know the facility's procedures for the follow-up of dialysis-associated infection and suspected adverse reactions during dialysis.

All personnel should receive training in accordance with OSHA's Bloodborne Pathogens Standard and Personal Protective Equipment Standard.[63,64,65] State and local regulations should be consulted for additional training requirements. Education should be ongoing so that the employee is updated on current practice standards and medical trends and maintains and improves competency.

Infection Preventionists’ Responses To Possible Dialysis-Assocated Problems

In response to possible dialysis-associated problems, IPs should:

- Report increased infections caused by Gram-positive organisms (i.e., coagulase-negative *Staphylococcus*, *S. aureus*). Most dialysis-associated infections with Gram-positive organisms are

usually related to the care of the access site. Develop a line listing of cases and look for common themes related to catheter insertion and maintenance.

- Report increased infections caused by water-associated Gram-negative organisms (i.e., *Pseudomonas, Stenotrophomonas, Serratia*) or endotoxin-like reactions. Symptoms in some patients may be very subtle and may not have warranted testing. Review patient records for increased incidence of fever (anything above 37.8°C or change from usual temperature pattern) or chills. In hemodialysis, these infections are most likely related to the dialysis environment. Obtain dialysate and processed water for culture and endotoxin testing. Review the water processing system and reuse procedures. Also review procedures for priming waste disposal. Confiscate any common use antiseptics (i.e., bottles of povidone-iodine) and multidose vials. Do not allow the drawing up of remains of medication from multiple vials into one syringe to have a full dose of a drug because this has been reported to contribute to bacteremias and endotoxin-like reactions.[73]Ensure careful and aseptic technique for preparation of medications and that needles and syringes for multidose vials are single-use for each patient.[74]Review machine disinfection and cleaning procedures. In peritoneal dialysis, review procedures for cleaning and disinfection of cycler, training materials related to bathing and other "water-related" activities, and the handling of antibiotic ointments, creams, and antiseptics.
- Report HBsAg in a chronic hemodialysis patient. Report the case to the local health authority, as required by state regulations. Segregate the patient until the case is ruled out or the patient is HBsAg negative, and do not reprocess the patient's hemodialyzer. Recommend that the patient's physician verify infection by sending Hepatitis B viral load, anti-HBs, and anti-HBc. Review the patient's medical record for recent medical interventions that could have resulted in infection (e.g., blood transfusions, invasive procedures, hospitalization) and for high-risk behaviors (e.g., injecting drug abuse, sexual activity, tattoos). Verify that the patient has not received Hepatitis B vaccine within the preceding 30 days (vaccine-related antigen may be detected). Review records of all other hemodialysis patients' routine laboratory results to identify other possible cases. Review hemodialysis unit procedures for possible breaks in routine procedures (e.g., medication distribution, routine cleaning and disinfection of dialysis machines and surfaces, sharing of common use items, violations of reprocessing procedures) that could have led to transmission from an unrecognized case.
- Report HCV seroconversion in a chronic hemodialysis patient. Report the case to the local health authority, as required by state regulations. Recommend that the patient's physician verify the infection. Review the patient's medical record for recent medical interventions that could have resulted in infection (e.g., blood transfusions, invasive procedures, hospitalization) and for high-risk behaviors (e.g., injecting drug abuse, sexual activity, tattoos). Review records of all other hemodialysis patients' routine laboratory results to identify other possible cases. Review hemodialysis unit procedures for possible breaks in routine procedures to determine if transmission may have occurred in the hemodialysis unit. If patient(s) seroconvert from anti-HCV negative to positive during a 6-month period, more frequent monitoring (every 1 to 3 months) may be indicated for a limited time to detect additional infections. If no additional cases are identified, semiannual testing can be resumed. If additional cases are identified, results of the review should identify possible control measures. Implementation of control measures should be carefully monitored for consistent application.

Conclusions

If strict chemical and infection prevention rules and recommendations are followed, dialysis procedures are safe and effective means of treating acute renal failure or are a life-sustaining treatment for ESRD until the patient undergoes transplantation or dies. Breaks in any dialysis procedure can have severe

and life-threatening implications for one or multiple patients. Dialysis patients may often have underlying diseases or conditions that may make early detection of outbreaks difficult because of the subtleties of their clinical presentation.

A proactive monitoring system for patient symptoms is needed to ensure that problems are detected as early as possible. The Dialysis Surveillance Network (see Supplemental Resources) is a voluntary way to participate in a structured surveillance program. Participation provides feedback on the individual dialysis unit level versus peers in the community.

With the majority of dialysis institutions functioning as stand-alone, for-profit ventures, it may not be in the best interests of the business venture to identify system problems that could lead to increased cost. Therefore, it is up to state and federal regulators, local health departments, and dialysis patients and their families to be proactive about asking important questions about routine dialysis procedures that affect the health of dialysis patients.

IPs should be proactive in monitoring dialysis facilities affiliated with their own institution. Use of contract services does not absolve the institution of responsibility. An in-house resource that is knowledgeable about regulatory requirements should be part of the team reviewing and enforcing contracts related to dialysis. IPs should also be vigilant for clusters of patients being admitted or seen in the emergency department after dialysis treatment. Possible clusters should be reported to the local health authority for assistance with prompt investigation and implementation of corrective measures, if necessary. If the cluster occurs in their own facility, IPs should feel comfortable reviewing standard dialysis procedures and implementing control measures when indicated.

Supplemental Resources

American Nephrology Nurses Association. Core Curriculum for nephrology nursing. Provides clinical "how to" information on dialysis. An excellent primer for the infection prevention professional who knows little about dialysis. Available at: **http://annanurse.org**.

Association for the Advancement of Medical Instrumentation (AAMI). The association is an alliance of engineering, medical, nursing, industry, and government professionals whose goal is to increase the understanding and beneficial use of medical devices and instrumentation. This is a must-have reference. CMS has adopted parts of these standards by incorporation, and every hemodialysis center that is receiving Medicare reimbursement must comply. Available at: **http://www.aami.org**. This book must be purchased for access. Every United States dialysis unit that is reimbursed by CMS should have a copy.

Centers for Disease Control and Prevention (CDC). Acute allergic-type reactions among patients undergoing hemodialysis—multiple states, 2007–2008. *MMWR Morb Mortal Wkly Rep*2008;57:124–125.

Centers for Disease Control and Prevention (CDC) and Healthcare Infection Control Practices Advisory Committee (HICPAC). Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Available at: **http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5210a1.htm**.

Centers for Disease Control and Prevention (CDC). Dialysis Safety. website is a compilation of resources for clinicians and patients. Includes links to guidelines and recommendations, prevention strategies, observation tools and checklists. Available at: **http://www.cdc.gov/dialysis/**.

Hallack R, Johnson G, Clement E, et al. Hepatitis C virus transmission at an outpatient hemodialysis unit —New York, 2001–2008. *MMWR Morb Mortal Wkly Rep* 2009;58(08):189–194.

International Society for Peritoneal Dialysis Guidelines. Expert panel of representatives from around the world has developed guidelines for optimal peritoneal access practices. Recommendations are evidence or consensus based and also addresses specific pediatric concerns. Available at: **http://ispd.org/lang-en/treatmentguidelines/guidelines**.

The Medical Education Institute. Core Curriculum for dialysis technician: A comprehensive review of hemodialysis. Fifth edition. Another primer for the infection preventioist. Basic information about dialysis concepts and equipment. Available at: **http://meiresearch.org/core_curriculum.php**, which will direct you to an Amgen representative who are the sponsors of this book.

National Health Safety Network (NHSN) tracking infections in outpatient dialysis centers. In order to meet the CMS ESRD QIP NHSN Reporting requirements, outpatient hemodialysis clinics must submit their 2013 dialysis event data by April 15, 2014, to receive credit for Payment Year 2015. To earn the maximum 10 points on the NHSN Dialysis Event Reporting measure, eligible facilities must report 12 months of dialysis event data collected during 2013 by April 15, 2014. Available at: **http://www.cdc.gov/nhsn/dialysis/index.html**.

National Kidney and Urologic Diseases Information Clearing House (NKUDIC), A service of the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), National Institutes of Health (NIH). Presents a basic overview of peritoneal dialysis procedures; contains good pictures and graphics. Available at: **http://kidney.niddk.nih.gov/kudiseases/pubs/peritoneal/**or **http://www.kidney.niddk.nih.gov**.

National Kidney Foundation, Kidney Disease Outcomes Quality Initiative (KDOQI). Clinical practice guidelines are available. Guidelines differentiate whether they are based on evidence or opinion. References cited may be viewed through links. Available at:**http://www.kidney.org/professionals/KDOQI/guideline_upHD_PD_VA/index.htm**.

Siegel JD, Rhinehart E, Jackson M, et al. Guideline for Isolation Precautions: preventing transmission of infectious agents in healthcare settings 2007. Atlanta, GA: U.S. Department of Health and Human Services, CDC, 2007. Available at:**http://www.cdc.gov/ncidod/dhqp/gl_isolation.html**.

International Organizations

Australia (Caring for Australasians with Renal Impairment—CARI)

Canada (Canadian Society of Nephrology—CSN)

European Renal Association–European Dialysis and Transplantation Association (ERA–EDTA): European Best Practice Guidelines (EBPG)

This society also has a Core Curriculum in Renal Technology. It can be accessed at: ***http://www.edtnaerca.org/pdf/education/Technicians_Core_Curriculum.pdf***

India (Indian Society of Nephrology – ISN) Draft Guidelines are available at:**http://www.isn-india.com/images/Image/HD_standards_Draft.pdf**.

United Kingdom (United Kingdom Renal Association—UKRA), Clincial practice guidelines can be accessed at:**http://www.renal.org/Clinical/GuidelinesSection/Guidelines.aspx**.

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Geriatrics

Author(s): Robin Roach, BSN, MS, CIC
Director, Infection Prevention and Control

Oregon Health and Science University
Portland, OR

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Abstract

Geriatrics is the branch of healthcare dealing with the physiological, pathological, psychological, economic, and sociological issues of aging.[1]*Old age cannot be specifically defined for the meaning differs among societies and cultures. In the United States, for example, 65 is often considered the beginning of old age for this is the common time for retirement from the workforce. People in the 65-and-over age group are often called senior citizens; however, the calendar number may not represent the age at which an individual feels old or begins to experience symptoms associated with "being old." It remains an unanswered question as to whether longer life expectancy means more years with chronic disease.*[2]*Average life expectancy in the U.S. continues to increase. In 1900, the average American was expected to live for 47 years. Today, the average life expectancy is 78.49 years.*[2]*As greater numbers of the population enjoy a long life, the field of geriatrics will play a more prominent role in healthcare.*

The field of geriatrics is an area of study for many scientists. The gerontologist healthcare provider is concerned with all aspects of the aging process, including the clinical, psychological, economic, and sociological issues encountered by older persons and the consequences for both the individual and society.[3]*To do this, they must understand the changes that take place in the human body during middle age that may lead to diseases later in life. The field is aided by the work of biologists, who study body processes involved in senescence (aging); psychologists, who investigate changes in mental reactions in older persons; and sociologists, who study the role of an aging person in a changing world. Nursing professionals focus on health, all levels of prevention and rehabilitation where possible, while public health professionals focus on maximizing health in old age by promoting healthy behavior in one's earlier years, thereby maximizing quality of life and independence and compressing morbidity and mortality.*[2]*This multidisciplinary approach is a great benefit to the field of geriatrics.*

Aging actually refers to the life history of the person or the processes of change in the person from the time of fertilization of the ovum until the death of the individual. The changes associated with senescence result in part from failure of body cells to function normally or to produce new body cells to replace those that are dead or malfunctioning. Normal cell function may be lost through infectious diseases, malnutrition, exposure to environmental hazards, or genetic influences. Among body cells that exhibit early signs of aging are those that normally cease dividing after reaching maturity.[4] One of the cardinal changes associated with aging that is relevant to infection preventionists (IPs) is a decline in immune function that occurs even among the healthy elderly, increasing their vulnerability to infection.

Key Concepts

- Age-associated changes are multifactorial and include changes in all major systems of the body that contribute to the risk for infection.
- Institutionalization in a healthcare facility may facilitate transmission of organisms, some of which are multidrug-resistant, between patients and staff, contributing to outbreaks.
- The increasing use of invasive devices, antimicrobials, and multiple medications contributes to the risk for infection.
- Comorbid conditions, such as diabetes, neurological disease, cerebrovascular disease, and cardiorespiratory disease are associated with physiological and functional impairment contributing to the risk for infection.
- Malnutrition, which is more common in the elderly, is associated with impaired immune function manifested by a decrease in cell-mediated immunity.
- Immunizations are recommended for adults over the age of 65 to decrease infection-related morbidity and to decrease mortality. It should be noted that the immune response from vaccinations for older adults may be less than the response in younger adults.

Background

The demographics of aging in the United States continue to change dramatically as the Baby Boomers (those born between 1946 and 1964) accelerate growth in the percentage and number of older people. In 2012, 13.5 percent of the population was 65 years and older, representing an estimated 42 million people in the United States.[5] Projections forecast that, by 2030, approximately 71.5 million people will be 65 and older, representing 20 percent of the total U.S. population.[6] In 2013, life expectancy at birth for the total U.S. population was 78.49 years with females living 81.05 years and males 76.05 years.[5] The aging of the U.S. population has been identified as a major public health challenge for the 21st century.[7] The dramatic increase in life expectancy of U.S. citizens has been attributed to improved medical care and prevention efforts, along with high levels of health insurance coverage for those over 65. These programs are primarily federal programs such as Medicare.[8] In a study conducted in 2012, 44 percent of older adults reported their health as excellent or very good as compared to 64 percent of adults 18 to 64 years old.[9]

The most common health conditions reported today for older adults are, in descending order, hypertension, arthritis, heart disease of all types, any cancer, and diabetes.[9] Historically, infectious

diseases and acute illnesses were the dominant health concerns for adults. The move from acute to chronic and degenerative illnesses has produced a major shift in the practice of geriatrics. Currently, approximately 80 percent of older Americans are living with at least one chronic condition.[10] To complicate this, growing numbers of older adults are living in poverty.[8]

In 2010, more than 13 million adults 65 years and older were discharged from short stay hospitals, a rate of hospitalization that is three times greater than younger age groups.[9] In addition, the average length of stay for older adults increases with the age of the patient, when compared to patients of younger ages.[9] A large percentage of medical-surgical patients, whether in acute care hospitals, long-term care facilities, or their own homes are over 65 years old.

Ultimately, 46 percent of the U.S. population will spend some time in a long-term care facility, with the majority residing in a nursing home.[11] The nursing home environment provides a setting that may foster the development and transmission of infectious agents. It is estimated that there are more than 1.5 million healthcare-associated infections (HAIs) occurring yearly in long-term care facilities. Infection is the most common reason for transfer of patients from a long-term care facility to an acute care hospital and accounts for about 33 percent of the transfers.[12]

This chapter focuses on some of the normal changes of aging and infectious conditions that pose specific risks. An understanding of the inherent processes of aging will enhance programs to prevent infections.

Basic Principles

Age-associated changes can contribute to the increased risk for infection either directly or indirectly.[13]

Infectious diseases are a frequent cause of morbidity and mortality in older adults. Numerous infectious diseases are more serious and have more drastic consequences for the elderly than for people of all ages. Disease presentation may be different in the older adult, causing a delay in diagnosis. In addition, faltering immune system function, muted vaccine response, thinning skin, glandular secretion reduction, and comorbid illnesses heightens the risk of infectious diseases in older adults.[14] Table 40-1 lists the body systems affected by age-associated changes.

INFECTIONS IN THE OLDER ADULT

Frequent healthcare encounters with hospitals, clinics, and skilled nursing facilities place older adults at risk for colonization with healthcare-associated pathogens including methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile,* along with endemic infections such as tuberculosis. For the older adult, many illnesses require treatment involving instrumentation, catheterization, ventilation, and surgical procedures, all of which increase the risk of infection.[15]

Bacterial Pneumonia

A leading cause of illness and death for older adults are respiratory infections both community and healthcare-associated.[12,14,15] The incidence of pneumonia among long-term care facility residents ranges from 0.3 to 2.5 events per 1,000 resident days.[12] The risk for pneumonia is greater in older adults due

to declined pulmonary function, reduced cough reflex, diminished mucociliary motion, and limited lung capacity. The aspiration of secretions is a chief cause of pneumonia for elderly patients. Lastly, swallowing impairment, concomitant chronic pulmonary disease, and smoking result in an increased risk of infectious respiratory illness among the elderly.[14] For more information on this topic, see **36. Pneumonia**.

Clostridium difficile Infection

The incidence of *C. difficile* infections (CDIs), a common and sometimes fatal HAI, is increasing, with the greatest impact being felt in those over 65 years. More than 90 percent of deaths from CDI have occurred in this population.[16] CDI may occur in healthcare settings where antibiotics are prescribed, in long-term care facilities, or within the community. A recent study found that although most cases are associated with healthcare contact, 75 percent experienced onset of CDI outside of the hospital.[16] For older adults, antibiotic exposure and inpatient or long-term care facility stays increase their risk of CDI. Unfortunately, older adults are more prone to CDI and its reoccurrence.[17] Initial treatment of CDI includes stopping the inciting antibiotic, followed by treatment with metronidazole or vancomycin; however, fidaxomicin may be associated with a lower rate of CDI recurrence.[17] Two new non-antimicrobial treatments that may be useful in reducing recurrent CDI are fecal bacteriotherapy and monoclonal antibodies. Infection control measures are essential to prevent environmental and healthcare personnel cross-contamination. For more information on this topic, see **72. Clostridium difficile Infection and Pseudomembranous Colitis**.

Table 40-1 Body System Effects of Age-associated Changes[13,14]

Cardiovascular 1. The valves of the heart, and blood vessels become thick and rigid as a result of sclerosis and fibrosis 2. The aerobic capacity of the heart decreases, resulting in a decline in oxygen delivery	**Musculoskeletal** 1. Declining muscle mass and endurance 2. Decreased bone density related to bone reabsorption exceeding bone formation 3. Decreased thickness and resiliency of cartilage 4. Development of erosion on articular surfaces (osteoarthritis)
Endocrine 1. Decreased secretion of trophic (concerned with building) hormones from the pituitary gland 2. Decreased efficacy of hormones on target tissues 3. Decrease in insulin secretion in response to a glucose load, while secretion remains normal at rest	**Neurological** 1. Gradual loss in the number of neurons, which may or may not relate to cognitive impairment

Gastrointestinal 1. Decrease or loss of digestive enzymes 2. Decreased intestinal motility and peristalsis 3. Changes in the normal bacterial intestinal flora 4. Decreased mucous production 5. Mastication problems and swallowing disorders	**Pulmonary** 1. Weakening of the intercostal respiratory muscles and diminishing of the chest wall elastic recoil 2. Decrease in partial pressure of oxygen 3. Decrease in the mucous transport/ciliary system resulting in decreased clearance of mucous and foreign material 4. Decreased gag reflex, which may contribute to aspiration 5. Increased esophageal reflux, which may contribute to aspiration 6. Presence of underlying illnesses such as cerebrovascular disease, malignancy, or cardiopulmonary disease
Hematopoietic 1. Declining marrow activity, especially in response to stress, such as blood loss or infection 2. Decrease in the formation and development of blood cells contributing to anemia	**Skin** 1. Thinning of all three layers of the skin—epidermis, dermis, and subcutaneous, leading to a decreased ability of the skin to function as a barrier to external factors 2. Reduction in sweat glands, resulting in less efficient thermoregulation of heat 3. Decreased number of sebaceous glands, resulting in less oil production 4. Decreased elasticity, resulting in diminished skin integrity 5. Impaired cell-mediated immune response
Eye 1. Decreased tearing 2. Decreased lysozyme production 3. Decreased blink reflex	**Smell and Taste** 1. Changes in smell, making food less appealing, resulting in decrease of appetite and weight loss 2. Loss of taste buds: Sweet and salty tastes are lost first, whereas bitter and sour tastes remain longer
Immunological 1. The function of T-cell lymphocytes, such as cell-mediated immunity, declines with age due to involution and atrophy of the thymus gland 2. Decreased T-cell helper activity and B-cell function, which results in decreased antibody production	**Urinary** 1. Decreased renal function 2. Loss of muscle strength necessary for urination 3. Bladder obstructions 4. Lack of sphincter control
Kinesthetic Sense 1. Joint receptors and muscles lose the ability to function and alter balance 2. Decreased ability to stop a fall from occurring	

Herpes Zoster

Herpes zoster, often referred to as shingles, is a result of a reactivation of the virus that causes chicken pox—that is, the varicella zoster virus. Diminished immune function, drugs, and illness can trigger the latent virus to reactivate. Herpes zoster is common in older adults and presents as a tingling prodrome with pain lasting at the site for 2 to 7 days, followed by a rash that becomes papular, then vesicular with increasing pain and burning. While serious illness is rare, management of the chronic pain and postherpetic neuralgia is especially challenging.[14] Prevention of herpes zoster with the new U.S. Food

and Drug Administration-approved zoster vaccine is possible.[18] For more information on this topic, see **80. Herpes Virus**.

Influenza

In elderly adults, influenza may present atypically with a less pronounced onset of fever and cough and more generalized complaints including mental status changes. Within congregate living settings, such as skilled nursing facilities, a cluster of residents with similar symptoms is often a clue to an influenza outbreak. For the older adult, whether vaccinated or unvaccinated, influenza causes high morbidity and mortality. In 2010, influenza and pneumonia were the ninth leading cause of death.[19] In addition, the number of elderly hospitalizations associated with influenza have increased over the past two decades. The Centers for Disease Control and Prevention (CDC) estimates that 60 percent of the seasonal influenza hospitalizations and 90 percent of the seasonal influenza deaths each year occur in the older adult.[20] Early diagnosis and treatment with appropriate antivirals may prevent death and may reduce the length of influenza illness. Elderly patients are especially at risk for secondary pneumonia and other complications from influenza.[14] For more detailed information on this topic, see **82. Influenza**.

Pulmonary Tuberculosis

Several age-associated changes in older adults predispose reactivation of latent tuberculosis infection (LTBI). Decreased cellular immunity, medications that suppress the immune system, comorbidities, and malnutrition, in addition to lack of LTBI treatment, contribute to an increased risk of tuberculosis (TB) reactivation. Although TB cases and deaths have decreased in the United States, individuals 65 years and older continue to have the highest rates, 5.1 per 100,000 population and comprise 22 percent of the reported cases of TB in the United States.[21] For more information on this topic, see **95. Tuberculosis and Other Mycobacteria** and **61. Long-Term Care**.

INFECTIONS FROM INDWELLING MEDICAL DEVICES

Intrinsic (natural) factors inherent to a patient's condition are determinants for acquiring an infection, but the use and abuse of invasive devices, such as urinary catheters and central lines, greatly increase the risk for infection. Devices provide a pathway or portal of entry for microorganisms to enter the body or act as inanimate surfaces where pathogens are protected from the immune system. Some bacteria that colonize both the surfaces of invasive devices and body tissue grow in microcolonies within a biofilm that encases the bacterial cell. A biofilm is defined as a matrix of polysaccharide (a material made of many simple sugars) that protects a collection of microbial cells.[22] Several factors account for the fact that biofilm-associated infections are resistant to treatment without removal of the invasive device, one of which is that the rate of penetration of antimicrobial agents through the biofilm may be reduced enough that they do not reach a sufficient concentration to be effective. The biofilm surrounding indwelling devices constitutes a major reservoir of antibiotic-resistant or tolerant bacteria.[23] More information on this topic is available in **34. Intravascular Device Infection**and **94. Streptococci**.

Urinary Tract Infections

In 1927, Frederick E. B. Foley developed the indwelling urinary catheter to control bleeding after transurethral prostatectomy surgery.[24] Since that time, the use of Foley catheters has become commonplace in the modern healthcare facility with utilization rates for chronic voiding dysfunction in

long-term care facilities ranging from 7 to 10 percent.[25] Indwelling urinary catheters pose a 3 to 7 percent daily risk of a urinary tract infection (UTI).[26] UTIs in older adults living in the community are the second most commonly diagnosed infection; whereas, for those living in long-term care facilities, UTIs are the most frequent infections.[27] UTIs are often overdiagnosed and overtreated.[28] The prevalence of asymptomatic bacteriuria, which does not always require treatment, and atypical presentations in the older adult (i.e., delirium) make the diagnosis of UTI challenging in this population.[29]

Factors that have been noted to contribute to an increased prevalence of bacteriuria in older adults include a decrease in cellular and humoral immunities, comorbidities such as chronic UTIs, and diabetes.[27] In addition, an indwelling Foley catheter or other urinary devise poses an opportunity for colonization leading to infection.[27] Recent strategies to reduce catheter-associated UTI focus on the appropriate use, assuring only trained personnel insert urinary catheters, and safety management during catheter use.[25,30,31] For more information on this topic, see **33. Urinary Tract Infection**.

ANTIMICROBIALS AND RESISTANCE

More than two million people become ill with antibiotic-resistant infections each year and an estimated 23,000 die annually from these infections.[32] Every major class of bacterial pathogen has shown the ability to develop resistance to one or more of the commonly used antibiotics, and the global crisis of resistance is serious. The CDC updated report on antibiotic resistance identifies four core actions to combat these deadly infections: preventing infections and preventing the spread of resistance; tracking resistant bacteria; improving the use of today's antibiotics; and promoting the development of new antibiotics and developing new diagnostic tests for resistant bacteria.[32] When choosing antimicrobials for the elderly patient, assessment of the renal and hepatic function is important. Also the following should be considered: (1) the site of infection, (2) the route of administration, (3) the mode of excretion of the antimicrobial, (4) any potential toxicity of the agent, and (5) the allergic history of the patient. The physiological changes that accompany advanced age may affect the absorption, elimination, and toxicity of antimicrobial agents. Because many elderly patients may be receiving multiple pharmacological agents, they are at high risk for drug interactions.[14]

Multidrug-resistant organisms (MDROs) such as MRSA, vancomycin-resistant *enterococci,* drug-resistant *Streptococcus pneumoniae*, Gram-negative bacteria (e.g., *Pseudomonas aeruginosa*, *Acinetobacter* species, extended-spectrum β-lactamase carrying organisms), and carbapenem-resistant *Enterobacteriaceae* are increasingly important causes of colonization and infections.[32] Antibiotic-resistant bacteria pose a significant hazard and resistance has been strongly associated with antibiotic use. Antibiotic pressure or selective pressure is the influence exerted by some factor (such as an antibiotic) on natural selection to promote one group of organisms over another. In the case of antibiotic resistance, antibiotics cause a selective pressure by killing susceptible bacteria, allowing antibiotic-resistant bacteria to survive and multiply.[32] Narrowing the choice of antibiotics by detection of the causative organism is recommended.[15]

Recent guidelines have addressed the judicious use of antimicrobial agents.[33] Elderly and disabled residents are at increased risk for colonization with resistant organisms, and colonization may persist for long periods (i.e., months to years). Residency in long-term care facilities or institutionalization has been

identified as a risk factor for transmission of MDROs. Both infected and colonized residents may serve as sources for the spread of MDROs in long-term care facilities. When MDROs become endemic within a facility, elimination is highly unlikely. Outbreaks or transmission of MDROs may occur within a facility. Effective infection prevention and control programs, such as antimicrobial stewardship, may limit the frequency and morbidity of outbreaks of infections in long-term care facilities.[12,34] Outbreaks are a problem for these facilities because of the great disruption they may cause, as well as the excess morbidity and mortality. For more information on this topic, see **26. Antimicrobials and Resistance**.

OTHER ISSUES

Elderly individuals living within congregate living facilities may be at a higher risk of infection due to the nature of communal living. Sharing entertainment or eating areas increases the ease of transmission and outbreaks associated with contaminated facility water or food, healthcare personnel cross-contamination, or visitor exposure. Congregate living facilities present a unique challenge for infection preventionists.[12] The high MDRO colonization rates, frequency of risk factors among the residents, as well as mobile residents may contribute to HAIs and outbreaks.[12] In addition to the previously identified healthcare-associated outbreaks, other outbreaks common in long-term care facilities include *Streptococcus pneumoniae, Chlamydia pneumoniae,* and *Legionella* spp. pneumonia; parainfluenza, respiratory syncytial virus, and other respiratory viruses; norovirus and other gastroenteritis; and scabies and conjunctivitis.[12] Specific prevention guidelines and recommendations for long-term care facilities have been published recently to reduce the risk of infections including MDROs and outbreaks.[12,34,35,36] For more information on this topic, refer to **61. Long-Term Care**.

MULTIPLE MEDICATIONS

Adults over the age of 65 consume 30 to 40 percent of all prescription drugs and an even higher proportion of over-the-counter drugs.[13] It is estimated that the average geriatric patient takes four to five medications a day.[37] The risk for an adverse medication reaction increases by 6 percent when two drugs are taken, to 50 percent when five different drugs are taken, and to 100 percent when eight or more medications are taken.[13] Age-related changes also predispose older adults to medication adverse effects: Adults over the age of 65 are more likely to have diminished ability to metabolize drugs as a result of declining kidney and liver function. Adverse drug reactions are observed two to three times more frequently in geriatric patients than in adult patients younger than 30 years.[12] Healthcare providers are encouraged to regularly review each patient's medications for potential interactions and side effects and, where possible, reduce or eliminate medications or select alternatives. Certain medications, such as steroids or other immunosuppressive agents, are likely to promote an increased frequency or severity of infection.

MALNUTRITION

Malnutrition is the result of inadequate ingestion of protein, calories, and/or micronutrients. Malnutrition alters the body's ability to prevent or combat infection. The prevalence of malnutrition rises substantially in hospitalized older adults; for nursing home residence, the prevalence may be even higher.[38] Many elderly patients are at an increased risk for malnutrition because of factors that limit the desire to eat, such as changes in the oral cavity, including loss of teeth, diminished saliva production, and difficulty

with mastication. A decrease in gastric secretion occurs with aging, and reduced pepsin hinders protein digestion and iron, vitamin B12, calcium, and folic acid absorption.

Altered nutritional status can affect all aspects of immune function. Cell-mediated immunity is most altered. The primary cells of cell-mediated immunity are the T-lymphocytes that recognize and destroy human cells infected with microorganisms. This function is extremely important for the destruction and elimination of infecting microorganisms (e.g., viruses, *Mycobacterium tuberculosis*, some parasites, and fungi) that are able to survive within the host cells, where they are "hidden" from antibody action.[33] For more information on this topic, read **47. Nutrition and Immune Function**.

PREVENTION AND TREATMENT OF VACCINE-PREVENTABLE DISEASES

The CDC recommends vaccinations for the older adult to help boost the immune system and to reduce the risk of contracting vaccine-preventable diseases.[39] Vaccines that are recommended for the older adult include: influenza (annually), tetanus-diphtheria-pertussis (Tdap; every 10 years), pneumococcal,[40] and zoster vaccines.[39]

Influenza Vaccination

The influenza vaccine is highly recommended for older adults. The CDC provides annual guidelines due to the necessity for new vaccine development every year to match the anticipated strains of circulating influenza.[41] Major changes in the virus occur every 2 to 4 years and necessitate changes in the vaccine composition. Antibody levels that result from influenza vaccination are short-lived requiring annual vaccination.[41] Influenza outbreaks are less likely to occur in facilities with a high level of vaccine coverage. Historically, long-term care facility staff influenza vaccination rates have been between 40 and 50 percent.[12] Due to this, most healthcare facilities are now moving to mandatory influenza vaccination for employees and residents.

Treatment and Control of Influenza

Use of antiviral drugs for treatment and chemoprophylaxis of influenza is a key component of outbreak prevention and control in institutions. In addition to antiviral medications, droplet precautions and establishing cohorts of patients with confirmed or suspected influenza, reoffering influenza vaccinations to unvaccinated staff and patients, restricting staff movement between wards or buildings, and restricting contact between ill staff or visitors has been used to stop the spread of influenza. Both adamantanes (amantadine and rimantadine) and neuraminidase inhibitors (oseltamivir and zanamivir) have been successfully used to control outbreaks caused by antiviral-susceptible strains when antivirals are combined with other infection prevention measures.[42,43] The neuraminidase inhibitors have activity against influenza A and B viruses, whereas the adamantanes have activity only against influenza A viruses.

When confirmed or suspected outbreaks of influenza occur in institutions that house persons of high-risk, chemoprophylaxis with a neuraminidase inhibitor medication (oseltamivir and zanamivir) should be started as early as possible to reduce spread of the virus. In these situations, having preapproved orders or plans to obtain orders for antiviral medications on short notice can substantially expedite administration of antiviral medications. Viral specimens should be collected from ill cases to help identify the outbreak strain and to assess for possible antiviral resistance. Chemoprophylaxis should be administered to all eligible residents, regardless of whether they received the influenza vaccination that

year, and should continue for a minimum of 2 weeks. If surveillance indicates that new cases continue to occur, chemoprophylaxis should be continued until approximately 7 to 10 days after illness onset in the last resident. Chemoprophylaxis should also be considered for all employees, regardless of their vaccination status, if there is a suspicion that the outbreak is caused by a strain of influenza virus that is not well matched by the vaccine.[42] The CDC issues official health advisories on the prevalence of influenza virus strains, resistant strains, and recommendations for antiviral treatment and chemoprophylaxis during the influenza seasons.[42] For more information on this topic, see **82. Influenza**.

Tetanus-diphtheria-pertussis Vaccination

Tdap vaccination has recently been added to the recommendations for those 65 years and older who have contact with infants to prevent infant pertussis.[43] Immunity to pertussis wanes with time. Rates of pertussis in adults have increased.[44] The recommendations of a single Tdap in place of the regular tetanus booster will help prevent cases of pertussis in adults and unvaccinated infants.[45]

Pneumococcal Vaccination

Pneumococcal vaccination, which protects against pneumococcal diseases that can cause severe illness in the elderly, is recommended for long-term care facility residents, along with all persons 65 years of age and older and persons 2 to 64 years who have underlying medical problems.[39,40] The pneumococcal vaccine produces antibody levels that last for several years. The pneumococcal vaccines are 50 to 85 percent effective in adults with healthy immune systems and, with advancing age, antibody levels may wane with time.[39] To learn more about this topic, see **36. Pneumonia**.

Zoster Vaccination

Prevention of herpes zoster is now possible due to a recently released vaccine. The vaccine is a one-time vaccination recommended for persons 60 years and older regardless of whether they had chicken pox.[18] In the vaccinated older adult, risk of herpes zoster is reduced by more than 50 percent.[14] To learn more about this topic, see **80. Herpes Virus**.

Conclusions

Twentieth century advances in protecting and promoting health among older adults have given us many opportunities to overcome the challenges of an aging society. As a result, by 2030, the nation's healthcare spending is projected to increase by 25 percent because of the demographic shifts. As more adults reach the age of 65, society is increasingly challenged to help them grow old with dignity.[3]

Knowledge and understanding of the inherent process of aging will assist in identifying age-associated changes that contribute to the increased risk for infection and infection prevention strategies. Antibiotic stewardship, periodic medication evaluations, the appropriate use of isolation precautions, assessing nutritional status, and adult immunizations are all key factors when caring for the elderly population.

Supplemental Resources

Centers for Disease Control and Prevention (CDC). Healthcare-associated infections (HAIs): Long-term care facilities. CDC Website. 2013. Available at: **http://www.cdc.gov/longtermcare/**.

Additional Resources

Centers for Disease Control and Prevention (CDC), Healthy Aging. Available at: **http://www.cdc.gov/aging**.

Centers for Disease Control and Prevention (CDC). National Center for Health Statistics Data Warehouse; Trends in Health and Aging. Available at: **http://www.cdc.gov/nchs/about.htm**.

Healthy People 2020 – Older Adults. Available at:**http://www.healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=31**.

National Health & Aging Trends Study. Available at:**http://www.nhats.org/**.

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Neonates

Author(s): Nancy Mendicino, RN, MSN, CIC
ICP Director

Christus Santa Rosa Health Care
San Antonio, TX

Gloria Morrell, RN, MS, MSN, CIC
Nurse Consultant

Centers for Disease Control and Prevention
Atlanta, GA

Susanna Leal Hernandez, BSN, RN, CIC
Infection Preventionist

Children's Hospital of San Antonio
San Antonio, TX

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Abstract

Neonates, especially those in a neonatal intensive care unit, are at high risk for infection. Colonized neonates are a major source of infection, and microorganisms can easily be transmitted between neonates on hands or equipment. Other sources include contaminated patient care supplies, infected personnel, family, and other visitors. The risk increases with decreased birth weight and/or gestational age and with exposure to invasive procedures and indwelling devices. In the newborn nursery, infections of the skin, mouth, and eye are most frequent; in the neonatal intensive care unit, bloodstream infections predominate. Coagulase-negative Staphylococcus, Staphylococcus aureus, Enterococcus, Enterobacteriaceae, *and* Candida*are most frequently isolated. Methicillin-resistant* Staphylococcus aureus*is a significant presence in the neonatal intensive care unit. Outbreaks of respiratory and gastrointestinal viral infections also occur. This chapter presents the essential elements of infection prevention in the neonate environment.*

Key Concepts

- The neonate is immunocompromised.
- Neonatal healthcare-associated infection rates vary with the level of care required.
- Invasive devices required for intensive supportive care of very premature and ill neonates increase infection risk.
- The high risk for severe infection and the difficulty in confirming diagnoses result in widespread use of broad-spectrum antibiotic therapy in the neonatal intensive care unit.
- The ill neonate readily becomes colonized with abnormal flora.
- Colonized newborns are a major source of infection for other infants in the neonatal intensive care unit.
- Transfer on the hands of caregivers is a major mode of transmission between infants.
- Contaminated patient care equipment and supplies are important sources of outbreaks and transmission.
- Bloodstream infections are the most prevalent infections in the neonatal intensive care unit.
- Prevention includes interventions related to nursery design, staffing, routine newborn care, hand hygiene, cleaning, and disinfection; augmented precautions for specific infections, infected mothers, personnel, family, and visitors with transmissible infections; outbreak management; enhancement of neonatal immune defenses; and antibiotic stewardship.
- State and national mandates for public reporting of healthcare-associated infections require ongoing evaluation of criteria for reporting.

Background

Healthcare-associated infections (HAIs) are an important cause of morbidity and mortality in neonates, especially those requiring intensive care. Advances in supportive therapy have resulted in survival of more low-birth-weight and ill infants, but also have created new infection risks. Prevention of infection in the premature infant who starts life in an intensive care unit with immature immune defenses that are further depressed by illness and invasive procedures is an ongoing challenge.[1,2,3]Although efforts continue to decrease infant mortality, the occurrence of preterm birth remains a concern. Fortunately preterm birth rates have been declining in the United States. Preterm births are defined as occurring before 37 weeks' gestation and accounted for 11.73 percent of all births in 2011.[4]

Organisms acquired from the mother during delivery frequently cause infections in the first few days of life. Subsequently, infections are commonly acquired from sources within the nursery environment. This environment includes many sources of microorganisms including other infants, healthcare personnel, families, and contaminated equipment and surfaces, thus prioritizing the importance of appropriate hand hygiene, cleaning and decontamination of the environment, and meticulous patient care technique. Other priorities for prevention and control of infection relate to limiting the number of invasive devices, promoting breastfeeding (unless contraindicated in rare situations due to maternal infection), and judicious use of antimicrobial therapy.[1,3,5,6]

Survival of very low-birth-weight infants (VLBW) and the increasing use of invasive therapies and widespread antibiotic use have resulted in opportunistic organisms such as coagulase-negative

Staphylococcus(CoNS), *Candida,* and Gram-negative organisms becoming more prominent.[7,8,9,10,11]In recent years, *Staphylococcus aureus (S. aureus)*has regained prominence and methicillin-resistant *Staphylococcus aureus*(MRSA) organisms have become increasingly significant pathogens in the neonatal intensive care unit (NICU) in many countries.[12,13,14,15]

This chapter focuses on infections acquired in neonatal care units, and the measures for prevention and control of these infections. Infections acquired from the mother in utero or during delivery are addressed in **43. Perinatal Care**.

Most HAIs in the NICU are related to invasive procedures and devices essential to preserving the survival of the infant. Lower birth weight and younger gestational age increase the risk of HAI due to immune system immaturity and extended hospital stay with prolonged use of invasive devices, parenteral nutrition, and antimicrobial therapy.[2,3,8]

Basic Principles

The neonate can acquire infection antepartum (prenatal) from the mother in utero, intrapartum (perinatal) during the period shortly before to shortly after birth (delivery), or postpartum (postnatal) from maternal, hospital, visitor, or other exogenous sources after delivery. For surveillance purposes, the Centers for Disease Control and Prevention (CDC) classifies all neonatal infection acquired during delivery or hospitalization as healthcare-associated unless present on admission or acquired transplacentally and become evident on the day of birth or the next day.[16]Distinction between perinatal and postnatal HAI is important, since infection prevention measures designed to prevent acquisition of microorganisms during neonatal care will not prevent perinatal acquisition from the mother. Routes of transmission of infection among patients include direct and indirect contact, droplet, and airborne spread. More than one route may be involved in the spread of infection. Direct contact transmission results from microorganisms transferred directly from one infected or colonized person to another without an intermediate source. Indirect contact transmission involves the transfer of microorganisms via an intermediate object or person, such as contaminated equipment or object or when appropriate hand hygiene is not performed. Droplet transmission occurs when respiratory droplets of the infectious person are spread a short distance in the air to mucosal surfaces of the recipient. Airborne transmission involves dissemination of either airborne droplet nuclei or small particles in the size range that may be inhaled; These infectious agents may be spread over long distances through air currents.[17]

DEFINITIONS

The following terms are used in the discussion of infection related to care in the neonatal setting:

- **Neonate**
  - Low birth weight – Any neonate weighing less than 2,500 grams at birth, regardless of gestational age.
  - Preterm – Any neonate born before and through the end of the last day of the 37th week (259th day). Onset of the last menstrual period is day one of the first week.
  - Term – Any neonate born from the beginning of the first day (260th day) of the 38th week through the end of the last day of the 42nd week (294th day).

- Postterm – Any neonate born from the beginning of the first day (295th day) of the 43rd week and later.[18]

- **Newborn nursery**refers to a nursery providing routine care and observation of healthy term infants and for late preterm infants born at 35 to 37 weeks who are physiologically stable.[19]
- **Special care nursery (SCN)** is a nursery providing care to ill neonates requiring 6 to 12 hours per day of nursing care but do not need intensive care.[19]
- **Neonatal intensive care unit**(**NICU**) refers to areas providing intensive care for severely ill newborns reflecting continuous nursing, cardiopulmonary care and other supportive services.[19]
- **Normal flora**refers to microorganisms that colonize the skin, mucous membranes, and gastrointestinal tract early in life. They are generally harmless and benefit the host by competitive exclusion of pathogenic organisms.
- **Colonization**is multiplication of microorganisms in a host without tissue invasion or injury.
- **Infection**refers to multiplication of microorganisms in the tissues of a host; infections can be asymptomatic or symptomatic.
- **Contamination**refers to the presence of microorganisms on or in inanimate objects or transiently transported on body surfaces such as hands.
- **Precautions**are interventions implemented to reduce the risk of transmission of microorganisms between individuals.
- **Isolation**refers to the physical separation of an infected patient from other patients.
- **Cohort**refers to the physical separation of a group of patients infected or colonized with the same organism from those who are not infected or colonized.
- **Antiseptic**is a germicide with antimicrobial activity designed for use on skin and body tissue.
- **Common vehicle**(common source) outbreak occurs when a contaminated source such as food, water, or medication is distributed to several persons.[20]

Infections Among Neonates

EPIDEMIOLOGY

Infection Rates

Infection rates of neonatal HAI are influenced by the patient population, level of care provided, proportion of infants of very low and low birth weight, extent of device utilization, surgical procedures performed, intensity of surveillance, types of infections reported, and denominators used.[3,21]The

American Academy of Pediatrics (AAP) published an expanded system in 2012 for classification of levels of neonatal care. These categories include:

- Level I well newborn nursery (stabilize ill newborn infants and those born before 35 weeks until transfer to a higher level of care and provide postnatal care to stable term and to stable infants born at 35 to 37 weeks)
- Level II special care nursery (level I capabilities plus: care for infants born at 32 weeks of gestation or later and weigh 1,500 grams or more who are moderately ill with problems expected to resolve

rapidly)

- Level III NICU (level II capabilities plus provide sustained life support, comprehensive care for infants born before 32 weeks and weighing less than 1,500 grams, full range of pediatric subspecialists, full range of respiratory support, and advanced imaging with urgent interpretation)
- Level IV regional NICU (includes level III capabilities and within an institution with capability to provide surgical repair of complex congenital or acquired conditions, to maintain full range of pediatric subspecialists and anesthesiologists, and to facilitate transport and outreach education)[22]

In newborn nurseries, infections are infrequent with reported rates of 0.3 to 1.7 per 100 admissions.[1]

Rates are much higher in NICUs. Rates were historically expressed as total infections per 100 admissions/discharges. Patient-days were used for NICUs, as infection risk is related to duration of stay.

The CDC's National Healthcare Safety Network (NHSN) stratifies data by birth-weight groups, using birth weight as a marker for severity of underlying illness. Data are also stratified by NICU level of care. Infection rates vary by device type and intensity of use (device days). Calculation of device-associated infection rates by device-days controls for this variation.[21] In NICU locations (level III or level II/III), data are collected for central line-associated bloodstream infection (CLABSI) (inclusive of umbilical catheter). Data are separated by five birth weight categories in grams (g): ≤750, 751 to 1,000, 1,001 to 1,500, 1,501 to 2,500, and >2,500. Data are also collected for ventilator-associated pneumonia (VAP) based on the same birth weight categories. These device-associated infection rates are determined based on number of infections per 1,000 device days. Infection rates provided by NHSN in April 2013 (inclusive of data summary for 2011) identified the following pooled mean NICU infection rates (by infant birth weight in grams).[21]

Microbial Colonization of the Newborn

Normal flora is protective. The absence or disruption of normal flora increases the ease of colonization with potentially pathogenic microbes and the risk of infection. Normal newborns are initially colonized by maternal microbial flora acquired during passage through the birth canal. After delivery, other microbes can be acquired from the mother, other family members, hospital personnel, or the inanimate environment. Normal flora is established in the healthy newborn within a few days of birth, with Gram-positive microorganisms predominating in the pharynx; *S. aureus* at the umbilicus, nares, skin, and rectum; CoNS at the nares, umbilicus, and chest skin; and anaerobic bifidobacteria, other anaerobes, and *Escherichia coli* (*E. coli*) in the gastrointestinal tract. Intestinal microbial flora is influenced by delivery method and by diet.[2,3,20,222324]

Limited maternal contact, delayed feeding, antibiotic treatment, and exposure to endemic NICU flora influence colonization of the infant in the NICU. Gram-negative aerobic *Enterobacteriaceae* predominate at many sites. Colonized infants serve as reservoirs of endemic NICU flora that can be transmitted to newly admitted infants.[7,24,25] NICU flora is influenced by the pattern of antibiotic use. Antibiotics suppress stool anaerobic flora and favor growth of aerobic Gram-negative rods, especially *Klebsiella, Enterobacter, Citrobacter*, and *Serratia*.[2,3,7,262728] In the NICU, the high risk of serious infection and the difficulty in making specific diagnoses result in widespread empiric use of broad-spectrum antibiotics. Intense antibiotic pressure favors emergence of resistant strains.[5,29,30] MRSA can cause epidemic or endemic infection.[13,14] There are numerous reports of outbreaks of infection with Gram-negative bacilli

resistant to multiple antibiotics.[7,8,29] Resistance appears to occur more rapidly with routine use of broad-spectrum cephalosporins than with penicillins and aminoglycosides.[2,26,29,31]

Sources of Infectious Agents

Colonized infants are a major source of infectious agents in the newborn nursery, SCN, or NICU. The predominant mode of transmission between infants is through transfer on hands of personnel.[7,25,323334]

Healthcare personnel have a tendency to contaminate hands by touching body parts or other fomites, especially during interrupted patient care. Hand contamination is usually transient, and hand hygiene interrupts transmission.[27,33,35363738] Personnel who are persistent carriers of potential pathogens have occasionally been implicated in transmission. Fingernail length and artificial fingernails have been associated with transmission of Gram-negative and fungal organisms.[2,32,394041]

Patient care equipment that is not adequately decontaminated between patients and shared supplies such as topical preparations used on the skin, cord, or eyes can be sources of infection. Outbreaks have been traced to contamination of resuscitation equipment, suction devices, ventilator circuits, rectal thermometers, and feeding bottles, and to the application of contaminated saline solution, mineral oil, ultrasound gel, glycerine, and antiseptic solutions. Contaminated hand hygiene agents also have been implicated.[1,5,17,27,29,414243] Environmental sources have also been identified as sources of infection.

Water reservoirs in the nursery are potential sources of microorganisms such as *Pseudomonas, Stenotrophomonas, Serratia*, and *Flavobacterium*. These organisms proliferate in water and in humid environments such as incubators, humidifier reservoirs, and respirator nebulizers and tubing.[1] A water bath used to thaw frozen plasma was associated with an outbreak of *Pseudomonas* infection.[1] Water reservoirs also can be a source of *Legionella*. The air supply of the NICU can become contaminated with spores of filamentous fungi if ventilation systems are faulty, if dust is allowed to accumulate, or if contamination of the system occurs.[45] Failure to implement appropriate control measures during construction or maintenance activities may cause contamination of air supply system and environment.[10,27,41,434445464748]

Although intravenous solutions and medications prepared commercially or in hospital pharmacies using current standards are rarely intrinsically contaminated, these can become contaminated during use. Unsafe injection practices, including lack of aseptic technique in withdrawing and injecting medications, reuse of needles and syringes for multiple entries into medication vials or solution containers,[49,50] and use of multidose vials, have been associated with transmission of infection in other healthcare settings.[5,8,17,29,42,43,49,50] Because of the tiny volume of medication doses and drug stability for the premature infant, it is not always possible to convert vials of certain medications to single use in the NICU. Blood transfusions have been sources of cytomegalovirus (CMV), Hepatitis A virus (HAV), Hepatitis B virus (HBV), Hepatitis C virus (HCV), human immunodeficiency virus (HIV), human T-lymphotrophic virus type I (HTLV-I), West Nile virus, Chagas disease, babesiosis, and malaria.[51]

Infant nutrition is another potential source of infection. Intrinsic contamination of commercial powdered infant formula with *Cronobacter sakazakii* has been reported.[52] Formula feeds and expressed breast milk can become contaminated during preparation, collection, or handling. Infections have been associated with contaminated blenders and breast milk pumps. Outbreaks of *Salmonella*, enteropathogenic *E. coli*,

and MRSA infections have been related to contamination of banked breast milk. Breast milk can also be a source of viruses such as cytomegalovirus (CMV), HIV, and HTLV-I. An appropriate exposure control process should be established to identify and follow up when expressed breast milk is administered to the wrong neonate.[51,535455]

Personnel or visitors with acute infections can infect infants, especially during community outbreaks. Adults and children with mild illness such as colds or unrecognized atypical pertussis can transmit potentially harmful pathogens to neonates. Asymptomatic persons can transmit varicella, measles, or rubella during the last few days of the incubation period. Family and sibling visitation may benefit hospitalized infants and should not increase risk of infection if visitation guidelines are established and followed.[17,51]

Factors That Affect Risk of Infection in Newborns

Newborn Factors

The immune system of the term newborn is immature, and deficits are especially pronounced in the premature infant. Defective chemotaxis and phagocytosis increase the risk for overwhelming bacterial and fungal infections. There is little antibody production by the fetus in utero. The newborn initially depends on antibodies acquired by passive transfer from the mother, which mostly occurs after 34 weeks of gestation. Infants born at fewer than 34 weeks of gestation may not receive sufficient amounts of antibody for protection. Preterm and term newborns respond adequately to most protein antigens, but response to polysaccharide antigens is poor in the first 2 years of life. Reduced cellular immunity results in ineffective control of intracellular pathogens such as *Listeria, Toxoplasma,*and *Salmonella*, as well as herpes viruses. Immune function can be further suppressed by sepsis, hypoxia, acidosis, and other metabolic abnormalities.[56]

The epithelial cells of the skin, gut, and respiratory tract form physical and chemical barriers that prevent direct entry of microbes into deeper tissues. Physical, mechanical, and chemical factors and colonization by commensal microbes contribute to the protective functions of the skin and of the mucosal epithelia of the gastrointestinal and respiratory tracts. Immaturity of these innate defenses is more pronounced in preterm neonates. Risk of infection can be increased by physical injury that disrupts epithelial integrity. The skin of neonates, especially preterm neonates, provides inadequate barrier function because it is fragile, very permeable, and easily traumatized. The stratum corneum matures rapidly postnatally, and by 2 to 4 weeks of life, is well developed in most term neonates, but can be later in preterm neonates. Congenital defects such as gastroschisis, omphalocele, myelomeningocele, or epidermolysis bullosa further impair barrier function. Prematurity, congenital anomalies, and perinatal hypoxia can result in a prolonged hospital stay and the need for invasive supportive devices, further increasing the risk of infection.[2,3,56]

The Nursery

Overcrowding and understaffing have been associated with increased infection rates and outbreaks in the NICU. These conditions, as well as inadequate access to or inappropriate placement of sinks and sanitizers, make it difficult for personnel to carry out appropriate hand hygiene. Routine cleaning and disinfection schedules of the environment and equipment need to be established and maintained. Each bedside should be considered a separate clean environment with no sharing of equipment. For healthy newborns, rooming-in programs and early discharge from the hospital reduce the newborn's risk of

exposure to other infants' flora and contact with personnel. Infection rates may be lower for infants rooming with their mothers than for those in communal nurseries.[2,5,19,34,57,58]

Invasive Procedures

Healthy newborns have limited exposure to invasive procedures. Fetal scalp electrodes are sometimes required and can provide a portal of entry for maternal genital organisms. Most infections are benign abscesses, but cellulitis, osteomyelitis, bacteremia, and herpes simplex virus (HSV) infection can occur. Percutaneous punctures for blood sampling may occasionally result in abscesses or osteomyelitis. Infection rates related to inpatient neonatal circumcision are <0.2 percent in the United States. Complications range from 0 to 2 percent for neonatal and child circumcisions in diverse worldwide settings with fewer occurrences in neonates than in children. [59] Superficial wound infections are the most common, but severe local infections and bacteremia can occur.

In contrast, infants in the NICU are often dependent on invasive life support measures. Disruption of the normal structural barriers to infection can be expected to present a higher infection risk in the newborn period than later in life. CLABSIs account for the majority of healthcare-associated bloodstream infections (BSIs) in NICUs and occur more frequently in neonates than in older children. [8, 21, 31, 60, 61, 62] BSIs are associated with approximately 5 percent of umbilical artery catheters and 3 to 8 percent of umbilical vein catheters. [21] Catheter disconnection, blood sampling, and colonization of the catheter hub have been identified as risk factors for CLABSI. Contamination of intravascular pressure monitoring devices has resulted in infection. Extracorporeal membrane oxygenation (ECMO) associated infections are lowest in neonates. Infection rates per 1,000 ECMO days are 10.1 for neonate, 20.8 for pediatric, and 30.6 for adult. Duration of bypass is the major risk factor. [63]

Urinary catheters are rarely used in neonates, but when used, they do increase the risk of infection. Implanted devices used to regulate intracranial pressure, such as ventricular reservoirs and ventriculoperitoneal shunts, also pose an infection risk. Preterm and ill neonates may require endotracheal tubes and ventilator support for prolonged periods. NHSN data indicate higher rates of VAP in VLBW infants than in larger newborns or in pediatric intensive care units. [21] The diagnosis of pneumonia in an intubated newborn is difficult and complicated by chronic lung disease. Further clarification of surveillance definitions specific to VAP diagnosis in neonates is needed.

General Characteristics of Infections Acquired in the Nursery

In the newborn nursery, most HAIs are superficial infections of the skin, mucous membranes, and eyes and are usually caused by true pathogens, such as *S. aureus*, including MRSA, or group A *streptococcus*. Infections with common viral pathogens also occur, especially at times of community outbreaks. [1]

In the NICU, BSIs predominate and are frequently associated with intravascular catheters. Pneumonia is the second most common infection. Skin, mucous membrane, and gastrointestinal infections also occur frequently. BSIs are more common, whereas surgical site infections (SSIs) and urinary tract infections (UTIs) are less common, than in older children and adults. [64] Opportunistic microorganisms are involved as well as true pathogens. CoNS are most frequently encountered, followed by *S. aureus, enterococci, E. coli, Enterobacter*, *Klebsiella*, *Pseudomonas aeruginosa (P. aeruginosa)*, and *Candida*. Outbreaks of

infection with Gram-negative rods and outbreaks of respiratory and gastrointestinal viral infections are frequently reported. There has been a shift in proportion of early-onset group B *streptococcus* (GBS) and *E. coli* BSIs after the first maternal-infant prophylaxis guidelines were published in 1996. [2, 41, 65, 66, 67]

Specific Microorganisms Causing Infections Acquired in the Nursery

Staphylococcus aureus

In the first few days of life, as many as 50 percent of newborns become colonized with *S. aureus*. Rates of colonization increase with prolonged hospitalization. Although this microorganism can be acquired from the mother, it often originates in the nursery, with colonized or infected infants serving as reservoirs. Transmission between newborns frequently occurs by transient carriage on the hands of personnel; this can be reduced by hand hygiene. Occasionally, outbreaks have been linked to personnel who were staphylococcal carriers and high-level shedders. Although newborn colonization is frequent, disease is less common. In healthy newborns, *S. aureus* causes minor skin infections in approximately 3 to 6 infants per 1,000 live births. Clusters of postpartum mastitis may indicate nursery transmission. Mothers should be questioned about the presence of abscesses or mastitis, when their healthy newborns develop *S. aureus* or MRSA infection with an unidentified source. [68,69] Infections are more frequent in NICUs, where invasive procedures and skin breakdown are important risk factors. Outbreaks of healthcare-associated MRSA have been reported in NICUs for decades. Infection can become endemic and can involve multiple strains. [13,14,15] Transmission also has occurred in newborn nurseries, with infection usually presenting after discharge. Delayed recognition of the nursery as the source of transmission can result in large numbers of mothers and infants becoming infected. Emergence of strains of MRSA in the community has translated into transmission of community-associated MRSA (CaMRSA) within the NICU and the newborn nursery environment. Since infants commonly become colonized with *S. aureus,* they would be at an inherent risk of colonization and infection with these resistant strains. [12,14,70,71,72,73] Studies suggest that CaMRSA is frequently acquired by vertical transmission from mother to newborn whereas healthcare-associated infections are usually acquired in the nursery, [74] but nursery outbreaks of CaMRSA strains have been reported. [70,71,75]

Most infections are benign, such as pustules, mild omphalitis, or conjunctivitis. More serious infections include bullous impetigo, cellulitis, soft tissue abscesses, surgical incision infections, bacteremia, pneumonia, osteomyelitis, and toxin-mediated syndromes such as scalded skin syndrome and staphylococcal toxic shock. *S. aureus* is an important cause of infections of ventricular drains and shunts. [68] The spectrum of disease with MRSA is similar. Some CaMRSA strains are more virulent than the MRSA strains that evolved earlier in hospitals and now count as significant causes of sepsis and disseminated infections with associated morbidity and mortality. [12,71,73] Diagnosis is made by isolation of organisms in cultures of specimens from the relevant clinical sites. For nonsterile sites, colonization must be distinguished from infection. [30,68] Screening tests are available for MRSA; are designed for quick identification of strains; and are helpful for surveillance screening, [76,77,78] but culture and determination of antibiotic sensitivity are required for management of symptomatic infections.

Minor *S. aureus* skin infections are generally treated with topical antiseptic or antibacterial agents. Focal or systemic infections with beta-lactam-sensitive strains should be treated with parenteral antistaphylococcal penicillins or first-generation cephalosporins. Vancomycin or linezolid is used for invasive MRSA infections. Abscesses should be drained and treated with the appropriate antibiotics. [30,68]

Appropriate hand hygiene should prevent most transmission between infants. Contact Precautions are recommended for infants with skin or wound infections. If an outbreak occurs, routine infection prevention measures should be reviewed and enforced. Cultures of the umbilicus and anterior nares of infants are used to determine the extent of the outbreak. Open wounds and lesions should be evaluated. Isolates should be typed to determine whether a single strain is present. Cultures may also be obtained from anterior nares and skin lesions of personnel who are epidemiologically linked to transmission. In addition, post-discharge surveillance for infections in recently discharged infants should be instituted. Alleviation of overcrowding and understaffing are important control measures. Antiseptic agents should be used for hand hygiene. [30,68] A MRSA outbreak can be controlled by implementation of Contact Precautions for infants with known or suspected infection. Active surveillance methods assist with identification of colonized infants. [17,71,78,79] When large numbers of infants are involved, cohorting has been successful. [13] New admissions, infected infants, and exposed infants should be cohorted separately. Outbreaks of MRSA have led to attempts to eliminate neonatal colonization by various means. Application of antiseptic agents to the umbilical stump has been used to delay or prevent colonization, with varying degrees of success. [68] Personnel identified as carriers and implicated on epidemiological evidence in dissemination of the epidemic strain should be removed from patient contact until they have received appropriate treatment to eradicate carriage. [79,80]

Coagulase-negative Staphylococcus

CoNS is normal flora of the skin and nose and rarely cause disease in healthy infants. *Staphylococcus epidermidis* is the most common species of CoNS found on the nasal mucosa and umbilicus of the newborn. These organisms have become important NICU pathogens as a result of the increasing survival of very premature infants and the extensive use of invasive devices. [2] CoNS produce large amounts of extracellular polysaccharide slime (biofilm) and other adherence factors that enhance their ability to grow on prosthetic materials such as intravascular catheters, endotracheal tubes, and cerebrospinal fluid (CSF) drains and shunts. Low birth weight (LBW), prematurity, prolonged NICU stay, infusion of intravenous lipid emulsions and parenteral hyperalimentation, and having a central venous catheter (CVC) are risk factors for infection. Bacteremia is the most frequent manifestation of infection. CoNS bacteremia prolongs the NICU stay but is not associated with an increased mortality rate. Pulmonary infiltrates are frequently seen on chest radiographs of infants with CoNS bacteremia. CoNS is the major cause of infection for ventricular shunt and drains and has been associated with a mild form of necrotizing enterocolitis (NEC). Endocarditis, abscesses, omphalitis, and SSIs occur occasionally. Diagnosis is by isolation of CoNS in cultures of specimens from normally sterile sites. Care must be taken to distinguish between true CoNS infection and culture contamination. Growth of the same phenotypic strain in more than one blood culture is more suggestive of infection than a single positive blood culture. NICU strains are frequently resistant to beta-lactam antibiotics so it is essential to determine susceptibility before use. Infections are usually treated with vancomycin or linezolid. Infections associated with intravascular and other devices may necessitate device removal. Combination therapy of vancomycin plus rifampin has been used for persisting bacteremia after catheter removal. Control

measures include aseptic technique for insertion and handling of intravascular and other percutaneously inserted devices and prevention of contamination during surgery. Addition of vancomycin to intravenous fluids reduces the incidence of neonatal CoNS bacteremia but is not recommended due to concern about induction of vancomycin resistance. [30,68]

Enterococcus

Enterococci are normal flora that may cause invasive disease in the immunocompromised newborn. Most infections are of late onset and frequently occur in LBW infants. CVCs, bowel resection, and prolonged hospitalization are risk factors. Infections including outbreaks with Vancomycin-resistant enterococci (VRE) have been reported. [81] Enterococcal bacteremia is often associated with focal infection such as NEC, soft tissue abscess, pneumonia, or meningitis. Diagnosis is by isolation in cultures of specimens from normally sterile sites. Enterococci are relatively resistant to antibiotics. Invasive infections are treated with ampicillin plus an aminoglycoside. Vancomycin is indicated for ampicillin-resistant strains. Invasive infections with enterococci including VRE can be treated with linezolid, daptomycin, or quinupristin-dalfopristin, but experience in neonates is limited. Contact Precautions should be used for patients colonized or infected with VRE. Antibiotics should be used judiciously to reduce selection of resistant strains. [17,30,81,82,83]

Group A Streptococcus

Group A *streptococcus* was an important cause of past outbreaks of neonatal sepsis. Infections are now reported infrequently but rare epidemics have still occurred in nurseries. In healthy newborns, infection might manifest only after discharge. Omphalitis is the most common presentation but severe skin infections, sepsis, and meningitis can occur. Diagnosis is by isolation in cultures of specimens from the relevant clinical sites. Infections are treated with parenteral penicillin. Clindamycin is added for treatment of toxic shock syndrome. Contact Precautions should be taken for infants with skin or wound infections, and Droplet Precautions should be followed for those with respiratory tract infection until 24 hours after onset of appropriate antibiotic therapy. Cohorting and application of bacitracin, triple dye, or chlorhexidine to the umbilical stump have been used successfully in outbreak control. Administration of prophylactic penicillin to all exposed infants has terminated some nursery outbreaks but the emergence of increased antibiotic resistance for other organisms such as *S. aureus* have been identified. [30,82,83,84]

Group B Streptococcus

Group B *streptococcus (GBS)*, a major cause of neonatal sepsis and meningitis, is usually acquired from the mother and is reviewed in **Chapter 43 Perinatal Care**. A CDC report in 2007 identified a decrease in the overall rate of early-onset GBS disease from 2003 to 2006. General findings recognized a shift in proportions of GBS and *E.coli* in early-onset BSIs after the first maternal infant prophylaxis guidelines were published in 1996 with significant reduction of early-onset GBS by 2002. The recommendations for prevention of early-onset GBS through universal screening of pregnant women and antibiotic prophylaxis as indicated have had a significant impact on early-onset GBS but no measurable reduction of late-onset GBS. Clinical manifestations of late-onset GBS sepsis are more difficult to diagnose; meningitis is frequently involved. [69,84,85,86,87]

Clostridium difficile

Clostridium difficile (*C. difficile*) is a spore-forming anaerobic Gram-positive bacillus that can cause serious gastrointestinal disease in adults and older children. In recent years, hospital strains of increased virulence have been identified. *C. difficile* is shed in feces and surfaces contaminated by feces may serve as reservoirs in hospitals. The organism produces two exotoxins, toxin A and toxin B, which are responsible for disease. The pathogenicity of *C. difficile* in infants is questionable because a high incidence of asymptomatic postnatal colonization has been detected in the newborn nursery and the NICU and the organism is considered a commensal organism in healthy newborns. Other causes of diarrhea, such as viral illnesses, should be considered in neonates even if *C. difficile* is identified. Nevertheless, *C. difficile* has been implicated in some outbreaks of NEC. More than 50 percent of neonates have *C. difficile and its cytoxins in stool specimens, usually with no clinical findings* for disease. [88,89,90,91]

Two common tests for *C. difficile* are the toxin test and stool culture. An enzyme immunoassay test detects toxin A, B, or both, and results can be reported in the same day. The toxins are also detected by cytotoxin assays, which are more sensitive for type A than for type B. The toxin in stool is very unstable and degrades at room temperature, rendering it undetectable within 2 hours after collection. Specimens must be tested promptly or kept refrigerated after collection. Toxin assay is less sensitive than the stool culture. The stool culture for *C. difficile* is the most sensitive test available for detection of the organism, but can identify nontoxigenic strains and can be associated with false-positive results. The test is very labor intensive, with results available within 48 to 96 hours. Results of treatment in the infant in one large study identified no significant change in clinical outcome. [90] Judicious use of antibiotics is recommended for prevention. Contact Precautions should be used for all infants with diarrhea, regardless of their *C. difficile* status. If an institution is experiencing an outbreak, use of soap and water is recommended instead of alcohol-based rinse for hand hygiene when caring for patients with *C. difficile*, since alcohol does not inactivate *C. difficile* spores. Equipment dedicated to the infant is recommended when possible. Excellent environmental cleaning and disinfection are essential. A bleach-based disinfectant should be considered with use according to label instructions. Many disinfectants are not effective against *C. difficile* spores and should not be used for cleaning of equipment potentially contaminated with spores, unless disinfection is supplemented with an effective product. [88,89,90,91,92,93,94,95,96,97]

Other Gram-positive Bacteria

Listeria monocytogenes infection is usually acquired from the mother. The organism is widespread in soil, vegetation, and water. *Listeria* is a foodborne illness, usually presenting in adults and older children as a mild, self-limiting disease. *Listeria* can be present in raw vegetables, unpasteurized cheeses, raw milk, and meats. Transmission generally occurs in the newborn transplacentally or via the birth canal, and can result in severe disseminated disease, sepsis, or meningitis. Nursery transmission is rare but has been reported with contaminated equipment and products, and possible surface contamination. [30,69,84,98] *Streptococcus pneumoniae* is an unusual cause of neonatal sepsis of maternal origin. [84]

Enterobacteriaceae

These Gram-negative bacilli include normal stool flora acquired at birth as well as organisms acquired in the nursery. *E. coli, Klebsiella*, and *Enterobacter* are the *Enterobacteriaceae* most frequently involved in HAIs. [69] Colonized infants serve as reservoirs. Transmission between infants is usually via hands, and contaminated patient care items have also been involved. [43] *E. coli* infection is frequently of maternal origin, but acquisition of nursery strains occurs. Klebsiella is more often of nursery origin and is an important cause of epidemic and endemic infections in the NICU. [27,43,99,100] This organism survives well on skin and is more resistant to drying than many other Enterobacteriaceae. Outbreaks have been associated with enteral feeding, infusion therapy, topical solutions, and other possible sources. [25,27,41] Enterobacter species have become common causes of neonatal HAIs. [29,41] Contaminated infant formula [52] and intravenous fluids have resulted in outbreaks. [29,50] *Citrobacter diversus (C. diversus)* infections affect healthy newborns as well as those in NICUs. Outbreaks are characterized by large numbers of colonized infants with small numbers of symptomatic infants and may involve single or multiple strains. Citrobacter strains may become endemic in NICUs. [84] Serratia causes serious endemic and epidemic infections in NICUs, especially in LBW infants. [27] Outbreaks are characterized by widespread gastrointestinal colonization and infections are often associated with invasive procedures. Contaminated intravenous fluids, equipment, breast pumps, and soap [84] have served as reservoirs. *Enterobacteriaceae* are common causes of bacteremia, meningitis, pneumonia, and UTI. [69,84,100] *Enterobacter* and *Citrobacter* sepsis may be manifested as meningitis with focal brain lesions. [84] Conjunctivitis is a frequent finding with *Serratia, E. coli, and Klebsiella* infection. [101]

Diagnosis is by isolation of organisms in cultures of specimens from the relevant clinical sites. For nonsterile sites, colonization must be distinguished from infection. [30,69,84] Treatment options include ampicillin, extended spectrum penicillins, aminoglycosides, extended spectrum cephalosporins, and carbapenems. NICU strains of *Enterobacteriaceae* are often resistant to multiple antibiotics. *E. coli* and *Klebsiella* can carry plasmid coding for production of extended spectrum beta-lactamases. *Serratia, Enterobacter*, and *Citrobacter* possess inducible beta-lactamases and can develop broad-spectrum resistance with antibiotic exposure. [30,84] Initial empiric therapy of HAI should be guided by the spectrum of antibiotic sensitivity of organisms known to cause infection in a particular nursery and adjusted when results of antibiotic sensitivity tests are available. Routine use of extended spectrum cephalosporins in NICUs should be avoided when possible because of rapid development of resistance. [30] Prevention including hand hygiene and disinfection of shared equipment should minimize transmission among infants. Appropriate handling and management of invasive devices, intravenous solutions, infant feedings, and topical products used for patient care are other important preventive measures. Infants with infections caused by multiple resistant strains should be placed on Contact Precautions. Special attention should be paid to separation of clean and dirty items and infection prevention practices within the nursery setting. This includes separation of formula and medication preparation from diaper changing and specimen handling activities, which is a challenge in crowded nurseries. [17,29,72,84,97]

Other Gram-negative Bacilli

P. aeruginosa is ubiquitous in moist environments and readily contaminates equipment. [84] The organism colonizes the gastrointestinal and respiratory tracts, especially in infants who receive antibiotic therapy, and may be transmitted between infants on hands. LBW infants are particularly at risk. [36,44,84]

Many Gram-negative bacilli can be acquired from contaminated water sources. [84] An outbreak of *Chryseobacterium meningosepticum* was related to contamination of intravenous lipid solution. [102] *Acinetobacter* species are frequently isolated from the inanimate hospital environment and can cause outbreaks of disease, especially in LBW infants. [47,84] Acinetobacter baumannii is a significant healthcare-associated pathogen. [28] Ralstonia pickettii bacteremia outbreaks have been reported. These Gram-negative bacilli have been linked to sepsis, pneumonia, conjunctivitis, and meningitis. [28,36,44,47,49,84,102] Diagnosis is by isolation of organisms in cultures of specimens from clinically relevant sites. For nonsterile sites, colonization must be distinguished from infection. Detection of Legionella requires special laboratory techniques. [5,30] *P. aeruginosa, Burkholderia cepacia, Stenotrophomonas maltophilia*, and *C. meningosepticum* are innately resistant to many antibiotics, and Acinetobacter species readily acquire broad-spectrum resistance. Treatment must be guided by tests of antibiotic sensitivity. Azithromycin has replaced erythromycin as the treatment of choice for *Legionella* infection, but experience in neonates is limited. Prevention involves elimination of reservoirs of standing water in the NICU, use of sterile water in nebulizers and humidifiers, disinfection of patient care equipment, and appropriate hand hygiene. [5,30] If *Legionella* infection is identified in a hospitalized neonate, a search for the contaminated water source should be undertaken and appropriate decontamination performed. [30,97]

Pertussis

Bordetella pertussis is the etiological agent of an acute, infectious cough illness. The initial catarrhal stage has an insidious onset with a cough that later becomes paroxysmal usually within 1 to 2 weeks and lasts 1 to 2 months. [30,103] Newborns may present with apnea, bradycardia, gagging, or gasping, and infants are prone to severe complications, including pneumonia, encephalopathy, and death. [30] Pertussis is highly communicable during the catarrhal stage and is transmitted through direct contact with respiratory secretions or via droplets. [17,30] Transmission in the NICU has been reported. [104,106] Healthcare personnel with unrecognized pertussis may introduce infection into the NICU. [105,107] Azithromycin is the treatment of choice and may shorten the period of communicability and reduce symptoms when given in the early stages. [30] Treatment is supportive. [30,103] Pertussis remains endemic in the United States in spite of routine childhood vaccination. The number of reported cases of pertussis has increased steadily since the 1980s. Immunity to pertussis wanes in 5 to 10 years after completion of childhood vaccination, leaving adolescents and adults susceptible to the disease unless vaccination is repeated. Since 2005, an acellular pertussis vaccine combined with diphtheria and tetanus antigens (Tdap) has been available in the United States. The Advisory Committee on Immunization Practices (ACIP) recommends that adolescents aged 11 to 18 and adults aged 19 to 64 years receive a single dose of Tdap. To reduce the risk of transmitting pertussis, all adults who anticipate having close contact with an infant aged less than 12 months (parents, grandparents aged <65 years, child care providers, and healthcare personnel) should receive a single dose of Tdap if they have not already received one. Women who have not previously received it should be given a dose of Tdap during pregnancy or in the immediate postpartum period. [104] Immunization of parents of infants in NICU has been recommended.

[108,109] Tdap can be given at an interval of as short as 2 years after the most recent tetanus vaccine, and shorter intervals may be warranted under certain circumstances. [104] Droplet Precautions are used for hospitalized infants with known or suspected pertussis. [17] Outbreak prevention and management measures include administration of azithromycin chemoprophylaxis to exposed infants and healthcare personnel, furlough of symptomatic personnel, and surveillance for additional cases. [30,105,107]

Tuberculosis

The newborn may acquire congenital or perinatal tuberculosis (TB) from an infected mother. [30] Infection is rare, and diagnosis may be delayed. [110] Infants are unlikely to transmit infection by coughing, but suctioning may generate infectious aerosols. There has been one report of transmission of TB between neonates. [111] Tuberculin skin test conversions have occurred in healthcare personnel exposed to infected neonates. [112] Infected healthcare personnel and mothers have exposed neonates to TB, but transmission to neonates appears to be extremely rare. [113,114,115] There is a lack of guidelines for surveillance and management of infants after exposure to a case of active TB in a NICU. Depending on the intensity of exposure, exposed neonates may receive isoniazid chemotherapy until infection can be excluded. [113,114,116] Neonates can rapidly develop severe disease, such as meningeal and disseminated TB, without acquiring tuberculin reactivity. Efforts should be directed at prevention such as protection from exposure, early detection, treatment of TB in pregnant women and mothers, TB screening of healthcare personnel, and attention to proper environmental air control and air exchanges. [97,115,116]

Candida

Candida species colonize 10 percent of newborns in the first 5 days of life and can be acquired from the mother or nursery sources. Systemic infection has increased in frequency with increased survival of VLBW infants designated as weighing less than 1,500 grams and extremely low birth weight (ELBW) infants identified as weighing less than 1,000 grams; *Candida* infection rates are 1 to 6 percent and 5 to 10 percent, respectively. [117] Full term infants with illnesses requiring invasive procedures are also at risk. [118] Antibiotic therapy suppresses normal flora allowing overgrowth of *Candida* and is the major risk factor for systemic candidiasis. Other risk factors include intravenous lipid administration, CVC, endotracheal intubation, use of H2 blockers, hydrocortisone therapy, abdominal surgery, and prolonged NICU stay. [117] Outbreaks have been associated with contaminated equipment and supplies. *Candida albicans* is the most frequently reported species, followed by *Candida parapsilosis, Candida glabrata,* and *Candida tropicalis*. [117,118] *Candida* infections of the mouth and skin are common in healthy newborns as well as in infants in NICUs. Systemic infections include candidemia, UTIs, and disseminated disease involving multiple sites including the lungs, meninges, eyes, gastrointestinal tract, and skin. [117] Nonspecific symptoms include fever, respiratory deterioration, hypotension, and gastric distention and resemble those of bacterial sepsis. Disseminated infection has a high mortality rate. [118] Diagnosis is by isolation of *Candida* in cultures of specimens from sterile body fluids or tissues, or by histopathology of biopsy specimens. Blood cultures may be negative even with extensive disease. As

colonization is common, isolation from nonsterile sites does not indicate infection, although it may identify infants at risk. [30,118] Superficial infections are treated with topical antifungal agents. [30] Amphotericin B is the standard treatment for systemic infection, although fluconazole is also used. [30,117,118] Newer agents such as echinocandins and second-generation triazoles look promising for treatment. [117] Intravascular catheters associated with infection should be removed. [118] Prevention of *Candida* infection in the NICU is a challenge, because most of the risk factors are unavoidable. Prophylactic nystatin does not prevent systemic disease. Fluconazole prophylaxis is under evaluation and may be beneficial for selected high-risk patients. [117,119] Despite concern that widespread use of fluconazole would select for resistant *Candida* species, resistance is still unusual. [120]

Malassezia furfur

Malassezia furfur is a lipophilic species of yeast causing fungemia in infants receiving broad-spectrum antibiotics, prolonged CVC use, and intravenous lipid infusions. Skin colonization has been associated with LBW and prolonged NICU stay. Lipid serves as a growth factor for the organism, permitting colonization of intravascular catheters and infection. Symptoms include apnea, bradycardia, interstitial pneumonitis, and thrombocytopenia. Although most infections are mild, severe pneumonia has been reported. Diagnosis is made by growth in blood cultures. Yield is enhanced by the use of lipid-supplemented media. Treatment consists of the removal of colonized catheters and discontinuation of lipid infusion. Amphotericin B is used for treatment of neonates with invasive disease. Consistent use of Standard Precautions should minimize transmission among infants. [117]

Filamentous Fungi

Infections with filamentous fungi such as aspergillosis and zygomycosis are rare but serious infections in the NICU. [117,121,122] These infections are a result of environmental contamination with dust containing fungal spores. Spores invade through inhalation and through cutaneous puncture sites or wounds. Air contamination can occur during hospital renovation. [117] Infection also has resulted from contaminated supplies. Risk factors include extreme prematurity, acidosis, renal failure, and treatment with steroids. Infection presents as pneumonia or skin infection that rapidly progresses to tissue necrosis, dissemination, and death. [30] Diagnosis is by histopathology of biopsy or autopsy specimens. Fungal cultures of blood or wound exudates are usually negative, but cultures of biopsy specimens may yield the organisms. [30] Treatment includes surgical debridement combined with antifungal agents such as amphotericin B, but treatment failures occur frequently. [30,117,123] Prevention involves maintaining air and patient care equipment and supplies free of dust and protecting neonates from dust during hospital renovation. [97] For information regarding construction and renovation, see **Chapter 116 Construction and Renovation**.

Respiratory Viruses

Neonatal respiratory viral infections can be acquired from the mother, other family members, hospital personnel, or other infants in the nursery. HAI reflects virus activity in the community. Infections with respiratory viruses are not commonly recognized in the newborn nursery since infants are usually discharged within the incubation period. Extensive NICU outbreaks can occur and involve large numbers of infants. [69,124] Nursery outbreaks have been documented for lower respiratory disease related to respiratory syncytial virus (RSV), adenoviruses, echoviruses, influenza A and B viruses, and parainfluenza virus infections. [69] These viruses are transmitted by direct, indirect, and large respiratory droplet contact. The viruses survive on hands, contaminated surfaces, and equipment long enough to permit transfer between patients. Virus shedding is prolonged in the newborn. Infected personnel contribute to healthcare-associated transmission. [30]

RSV infections are one of the most common respiratory diseases of early childhood. [30] In one hospital outbreak, 25 percent of infants located in the NICU for more than 6 days acquired RSV during the community outbreak. [125] One NICU study evaluated morbidity and patient outcomes associated with an RSV outbreak along with the economic burden. This NICU outbreak involved nine infants who were clinically stable until the RSV infection. Intubation became essential for five cases, with required ECMO for 9 days with one infant. Fortunately, all infants survived; 49 exposed infants received prophylactic palivizumab. More than $1.15 million in hospital charges were attributable to the outbreak. [126]

Parainfluenza virus type 3 (PIV3) was reported to cause more than 30 percent of the acute respiratory infections in infants and children. [127] In one outbreak of PIV3 infection, the attack rate for the neonate nursery was 25 percent; these patients were extremely preterm infants (gestational age of 26 to 28 weeks). [128] Another PIV3 outbreak was identified in an intermediate care nursery. [129] Contiguous bed space, nasogastric tubes, and endotracheal intubation are risk factors for transmission of many respiratory viruses. [30,124] Human metapneumovirus (hMPV) is another viral pathogen resulting in respiratory disease in children and newborns. Preterm birth is a likely risk factor for severe disease, but the degree of risk is not fully defined. [30] NICU outbreaks of influenza have been reported. One study of influenza A identified a NICU outbreak controlled with infant antiviral prophylaxis; compliance of healthcare personnel with annual vaccination was reported as very low. [130]

RSV infection may present with nonspecific signs during the first few weeks of life (including apnea, lethargy, irritability, and feeding difficulties). Severity may vary from mild upper respiratory tract disease to pneumonia. Disease is more severe in premature infants. [30] In concurrent outbreaks, features of PIV3 and rhinovirus infections were similar to those of RSV. [129] Symptoms of hMPV resemble those of RSV but tend to be milder. [129] Infants with influenza may have respiratory disease or signs and symptoms resembling bacterial sepsis. [129,130] Manifestations of adenoviral infection include conjunctivitis, upper respiratory tract disease or pneumonia, or a sepsis-like syndrome. Severe disease has occurred when adenovirus infection was acquired from a symptomatic mother, presumably because the mother had no antibody to provide passive immunity to her newborn. [30,129]

Diagnosis is frequently by isolation of virus in cell culture or direct antigen detection performed on nasopharyngeal or endotracheal secretions. Assays that identify viral ribonucleic acid (RNA), that is reverse transcription polymerase chain reaction (RT-PCR) assays, in respiratory secretions are being used with increasing frequency. These newer assays have significantly increased RSV detection rates

over viral isolation or direct antigen, but they will detect viral RNA that may persist after cessation of shedding of infectious virus. [30] Various diagnostic tests are now routinely available for diagnosis of viral respiratory pathogens. Rapid tests detect viral antigens by assays providing results in minutes, direct fluorescent antibody (DFA) tests support same-day diagnosis, viral culture provides confirmation, and PCR-based methods detect RNA; testing options should be prioritized to evaluate high-risk neonates to direct treatment and control measures. [129]

Primary treatment of RSV is supportive, involving hydration and respiratory monitoring and stabilization as needed. Ribavirin is no longer recommended for routine use due to conflicting results from efficacy trials, and the concerns about potential toxic issues associated with aerosol administration. Ribavirin is still a treatment option for selected patients with documented potential life-threatening infection with RSV. [30] For anti-influenza prophylaxis, oseltamivir treatment was noted as effective and well tolerated by premature infants. [30,130]

Prevention measures include consistent use of Contact and Droplet Precautions, including disinfection of any shared equipment, to prevent transmission from infected infants. [17] A mother with a respiratory infection should wash her hands before contact with her infant and any items in the nursery, and take measures to prevent contact of infant with potentially contaminated tissues and other fomites. [5] A mask may be needed depending on the nature of the symptoms. Visitation arrangements should be prioritized for parents, but special control measures may be needed to provide a safe environment for all patients. Other family members with respiratory infections should not visit unless it is absolutely necessary. Personnel with viral conjunctivitis should be restricted from patient care. Ideally, personnel with signs and symptoms of potential viral respiratory illness should be restricted from the NICU. If restriction is not feasible, potentially infected personnel should take careful precautions to prevent transmission of virus to their patients. [80] These precautions include washing hands after any contact with their respiratory secretions or used tissues, avoiding touching of their eyes and nose, wearing gloves and surgical masks during patient care, and following careful hand hygiene before all contact with patients and equipment. During RSV season, infants younger than 32 weeks' gestation and those with chronic lung disease or hemodynamically significant cardiac disease should receive prophylaxis with RSV monoclonal antibody (palivizumab). [30,124,131] Nursery personnel should receive influenza vaccine annually, as should the parents and other future household and close contacts of infants. [30] Vaccination in pregnancy reduced occurrence of influenza illness by two-thirds in newborns up to 6 months of age. [132] Limitations in options for prophylaxis for many viral diseases lead to difficult decisions about use of an unproven therapy with the potential for life-threatening diseases. [133]

Rotavirus

Rotavirus causes outbreaks in normal newborn nurseries and NICUs and can become endemic. [90] Infection rates have been reported up to 40 percent during nursery outbreaks. [90] The virus transmits among infants, by contaminated hands or equipment, and survives for prolonged periods on environmental surfaces. [134] Neonatal rotavirus infections are frequently asymptomatic or mild, but severe disease with bloody diarrhea or NEC can occur. [90] Abdominal distention and bloody mucoid stools may

be more prominent than watery diarrhea in premature infants. Lack of proteolytic enzymes or receptor sites in the newborn gut, the presence of inhibitors in breast milk, and attenuation of endemic nursery strains have been proposed as possible explanations for asymptomatic infection in newborns. [90,134]

Virus is detected in stool by antigen detection assay, electron microscopy, or specific nucleic acid amplification. [30] Treatment is supportive to correct or prevent dehydration. Routine hand hygiene and disinfection of equipment among patients should prevent transmission from asymptomatic infants. [90] Contact Precautions are recommended for infants with diarrhea.

Rotavirus vaccine should be given at discharge of clinically stable preterm infant, if at least 6 weeks of postnatal age. [30,135] One live, oral vaccine is licensed as a three-dose series. A second live oral rotavirus vaccine is licensed as two-dose series. ACIP recommends routine vaccination of infants in the United States with rotavirus vaccine starting at 2 months of age; vaccine can be given as early as 6 weeks of age. Vaccination should not be initiated for infants older than 15 weeks of age because of insufficient data on safety of giving the initial dose of vaccine in older infants. As vaccine virus is shed in the stool, the vaccine should not be given to neonates who remain in the hospital, but should be given at or after discharge. [134]

Enteroviruses (Nonpolio) and Parechovirus Infections

Most neonatal enteroviral infections are acquired perinatally from the mother (see **Chapter 43 Perinatal Care**). Outbreaks have been reported in newborn nurseries and in NICUs associated with community outbreaks. Echovirus and coxsackievirus B virus are most frequently encountered. [136,137] The most consistent source of original nursery infection in the outbreaks was from mothers to their infants, but transmission continued within the nurseries and NICUs by the fecal-oral route. Viral shedding may continue for a few weeks after resolution of symptoms. [30,136] Mouth care, gavage feeding, proximity to an infected child, and care by the same caregivers are risk factors for infection. [30,136]

Clinical features include nonspecific febrile illness, rash, gastrointestinal and respiratory symptoms, and aseptic meningitis as the usual manifestations. The disease may resemble bacterial sepsis, and severe hepatitis, encephalitis, or myocarditis can occur. Infection is diagnosed by isolation of virus in cell culture of specimens from throat, stool, CSF, or blood. Assays to detect viral nucleic acid may be more sensitive than cultures, but availability is limited. [30] Treatment is supportive. Immunoglobulin intravenous (IGIV) has been used in severe neonatal infections, but there are no data on efficacy. [30] Pleconaril, an investigational antiviral drug, has been used in some cases of severe neonatal disease but is not commercially available. [30] Routine hand hygiene and disinfection of equipment between patients should prevent transmission from asymptomatic infants. Contact Precautions are recommended for those with documented infection.

Hepatitis A

Nursery outbreaks of Hepatitis A virus (HAV) infection are rare, but transmission may be widespread. An infant infected by blood transfusion or by acquisition from an infected mother may introduce the virus into the nursery. [30] The virus is excreted in stool and can be transmitted to other infants, personnel, and

parents by fecal-oral contact. Rare NICU outbreaks were related to neonates infected through transfused blood or an infected mother with subsequent transmission to other neonates and staff. [30,129]

Infection is usually asymptomatic in the newborn, yet virus excretion can continue for several months in preterm infants. [129] Outbreaks may be recognized late, after personnel or parents become ill. Infection is diagnosed by the presence of immunoglobulin M (IgM) antibody to HAV. [30] Treatment is supportive. Routine hand hygiene and disinfection of equipment between patients should prevent transmission from infants with unrecognized infection. Personnel should refrain from consuming food or beverages in the nursery. Infants known to be infected should be placed on Contact Precautions. Prophylactic immune globulin is not routinely indicated for exposed healthcare personnel, but administration to exposed contacts may be necessary to control an ongoing outbreak. [30] Immunoglobulin is recommended for newborns as soon as possible after delivery if the newborn had maternal exposure from disease 2 weeks before until 1 week after delivery. [129] HAV vaccine should be considered in outbreak control, if repeated exposure of personnel is anticipated. In 2006, ACIP recommended routine hepatitis A vaccination of all children at 1 year of age. [30]

Hepatitis B

Hepatitis B virus (HBV) is an important form of primary viral hepatitis in the neonate. Newborns acquire HBV from mothers with chronic or acute infection in pregnancy (see **Chapter 43 Perinatal Care**). Infection is almost always asymptomatic in the infant, but neonatal acquisition carries a high risk of lifelong chronic infection and serious liver disease in adulthood. Transmission usually occurs at delivery, and administration of HBV immunoglobulin (HBIG) and vaccine at birth prevents infection in the newborn. [30,138,139] Transfusion-acquired HBV infection in the newborn has rarely been reported, [129] even in the era before universal screening of blood donors, probably because infections were asymptomatic and not recognized. Universal vaccination for HBV is part of the infant immunization schedules in the United States and in many parts of the world, usually beginning as birth dose given at or before 24 hours of age. [139]

Prevention of neonatal HBV includes maternal screening for HBV. [129] Infants born to mothers with active HBV disease or carriers of HBV require administration of HBIG and HBV vaccine within the first 12 hours of life, with three doses of HBV vaccine given beginning at 1 month of age. Premature infants weighing less than 2,000 grams may respond suboptimally to the HBV vaccine dose given at birth and should receive an additional dose at 30 days of age. Vaccination schedule continues with two further doses. Infants born to mothers negative for HBV surface antigen should receive HBV vaccine at birth, with continued vaccination schedule of two subsequent doses. Preterm infants weighing less than 2,000 grams born to a mother negative for surface antigen HBV should receive the first HBV vaccine dose at 30 days of chronological age and complete vaccination schedule with two additional doses. [30]

Hepatitis C

Prior to routine blood donor screening for Hepatitis C virus (HCV), multiply transfused NICU patients were at risk for HCV virus. [140] Screening of blood for HCV is now routine in the United States and many

other countries. Care should be taken to minimize transfusion in neonates in countries that do not have routine HCV blood screening methods and to offer screened blood whenever possible.

Vertical transmission of HCV from mother to child occurs at a rate of about 5 percent and occurs mainly from mothers who are HCV RNA-positive. [129] HIV co-infection is a risk factor for vertical transmission. [30]

Varicella-zoster Virus

Varicella infection acquired in utero or perinatally from an infected mother is discussed in **Chapter 43 Perinatal Care**. Varicella may be introduced into the nursery by employees, mothers, or visitors with unrecognized infection, or by an infant with perinatal varicella. Healthcare-associated transmission is rare in newborn nurseries, [30] including LBW and preterm infants. r141 The virus is transmitted by the airborne and contact routes, and transmission may occur before onset of the rash. Neonatal varicella can range from mild to severe. Extensive skin and mucosal lesions, pneumonia, hepatitis, or meningoencephalitis can occur. Varicella seronegative premature newborns are at risk for severe disease. [30,129] Laboratory diagnosis is rarely required if disease manifestations are typical. If diagnosis is questionable, vesicle scrapings should be examined by immunofluorescence or histopathology for intracellular viral inclusions, or viral culture of skin or mucosal lesions should be performed. [30,129] Treatment is with intravenous acyclovir. [30]

Airborne and Contact Precautions should be taken for infants with varicella, and Airborne Precautions should be taken for asymptomatic exposed neonates. Continue the precautions for exposed infants for 21 days from the last exposure and for 28 days for infants given varicella-zoster immune globulin (VZIG or referred to as Vari-ZIG) or IGIV. Visitors to the nursery should be questioned about presence of rash compatible with varicella or zoster and immunity to varicella, and if nonimmune, recent contact with varicella. Nonimmune healthcare personnel should receive varicella vaccine. Hospitalized premature infants of seronegative mothers and all hospitalized infants born before 28 weeks of gestation should receive prophylactic VZIG or IGIV (depending on availability) if exposed to varicella in the hospital. [30,138,139]

Other Viruses

Neonatal HSV, CMV, and HIV infections are usually acquired from the mother before or during delivery and are discussed in **Chapter 43 Perinatal Care**. Transmission of HSV in the nursery is rare, but small outbreaks have been reported. [129] Infection transmission to an infant from healthcare personnel is rare but has been reported. [129] Transfusion-acquired CMV infection has occurred in LBW infants of seronegative mothers. [129] Disseminated CMV infection has been reported in infants of CMV-seronegative mother after exposure to large volumes of unscreened blood products. [142] Premature newborns should receive CMV-negative blood products. Transmission of CMV among infants in the NICU is extremely rare. Since transmission requires direct inoculation of mucous membranes with fresh infectious secretions, it can be prevented by hand hygiene after handling respiratory secretions or diapers. [5] HIV was transmitted to neonates by blood products before programs for universal screening of blood donors

were instituted [143] and may continue to be transmitted through blood products in countries without access to donor screening.

Sites of Infection

Bloodstream Infections

BSIs occur in 1 to 8 newborns per 1,000 live births [84] and account for 30 percent of NICU infections. [7]

Early-onset BSI occurs shortly after birth as a result of infection acquired in the birth canal and is characterized by fulminant multisystem disease with a high mortality rate. Risk is increased with prematurity, LBW, prolonged rupture of membranes, maternal chorioamnionitis, and maternal fever. Historically, GBS and *E. coli* were the major etiologic agents; however, a shift occurred after the first maternal infant prophylaxis guidelines were published in 1996. There was a decrease in the incidence of early-onset GBS sepsis after the institution of maternal intrapartum antibiotic prophylaxis. [66,67] Listeriosis occurs less frequently. *Streptococcus pneumoniae* infections are uncommon but are encountered with increasing frequency in some areas. [84,138] Early-onset BSI has also been reported with *Haemophilus influenzae*, usually nonencapsulated nontypable strains. *Campylobacter fetus* is an uncommon cause of severe early-onset BSI and is usually of maternal origin. [84,138] Late-onset BSI usually occurs after the first week of life. The microorganisms involved in BSI are of maternal or community origin and are similar to those that cause early-onset infection, but late-onset BSI is more often associated with focal infection, especially meningitis. Pathogen changes were also noted in late onset BSIs, showing an increase in proportion of *S. aureus* and enterococci in more recent years. Late-onset BSIs of nursery origin are usually caused by CoNS, *S. aureus*, enterococci, or Gram-negative bacilli. [7,8,44,84,144] In resource rich countries, CoNS and *Candida* species are the major organisms causing BSI in infants kept in the NICU for more than 30 days. Gram-negative pathogens prevail in less resourced countries. [3,8,58]

The majority of BSIs of nursery origin are associated with CVCs. LBW remains a risk factor when CVC use is considered. Other reported risk factors for BSI include parenteral nutrition, surgery, treatment with H2 blockers, mechanical ventilation, and dexamethasone therapy. [1,62]

The newborn has a limited number of ways of responding to stress. Signs of infection can be subtle and can resemble those of a number of noninfectious conditions. Features of bacteremia are similar to those of disseminated fungal, HSV, or enteroviral infection. General features include lethargy, poor feeding, temperature instability, hypoperfusion, glucose intolerance, acidosis, coagulopathy, thrombocytopenia, and leukopenia or leukocytosis. Dyspnea, apnea, cyanosis, jaundice, hepatomegaly, and abdominal distention can occur, as well as irritability or decreased level of consciousness. [45,84]

Diagnosis is by isolation of microorganisms from blood cultures. Early-onset or late-onset BSI of maternal or community origin is treated empirically with ampicillin plus an aminoglycoside or third-generation cephalosporin. For late-onset BSI of nursery origin, empiric antibiotic therapy is based on sensitivities of organisms known to cause HAIs in a specific nursery. The likelihood of *S. aureus*, *Pseudomonas,* or *Candida* infection should be assessed. In general, a broad-spectrum beta-lactam antibiotic (ampicillin) and an aminoglycoside (gentamycin or tobramycin) should be used. Vancomycin may be required if *S. aureus* (including MRSA) is present in the nursery. [84,138] For many antibiotics, the volume of distribution is larger and the half-life longer in the newborn than in older infants and children.

A larger individual dose per kilogram and increased intervals between doses are often required. For drugs with a low therapeutic index, such as vancomycin and aminoglycosides, serum levels should be monitored. Abscesses should be drained. Removal of CVC is often required. [69]

Prevention of early-onset BSIs, acquired perinatally from the mother, involves prevention, diagnosis, and treatment of infection in the pregnant woman, intrapartum antibiotic prophylaxis, and prevention of obstetrical complications known to be associated with increased intrapartum transmission. [1]

Prevention of BSIs acquired in the nursery requires strategies to reduce risk of infections related to invasive procedures and devices, especially intravascular lines. The efficacy of strategies targeted to reduce CLABSI rates in the NICU has been demonstrated. [2,3,6,11,31,38] The Institute of Healthcare Improvement codified specific components or care bundles of best practice interventions. These include hand hygiene, maximum barrier precautions during insertion (full body drape, cap, mask, sterile gloves, and gown), chlorhexidine gluconate (CHG) skin antisepsis, catheter selection site, and daily review for line necessity. [145]

The use of CHG as a topical antiseptic for the prevention of line-associated bacteremia has become a common practice in recent years. The CDC, in its *2011 Guideline for Prevention of Intravascular Catheter-Related Infections*, recommends that >0.5 percent CHG preparation with alcohol be the agent of choice for vascular access. [60] Alcohol combined with CHG appears to be superior to aqueous CHG. A concentration of 2 percent CHG in 70 percent alcohol has become the product of choice for CVC insertion in many countries [145,146,147r] but there is limited experience with this product in neonates. A preparation of 0.5 percent CHG in 70 percent alcohol has been used extensively in newborns for skin preparation prior to intravenous (IV) insertion and for IV site care. However, alcohol is known to cause serious burns in extremely premature neonates when exposure occurs shortly after birth. There are several published case reports of severe burns, all in neonates of younger than 28 weeks' gestation and less than 1,000 grams birth weight with cutaneous exposure to 70 percent alcohol or CHG in 70 percent alcohol on the first day of life. [148,149] Skin antiseptics containing significant amounts of alcohol should be avoided in very young infants younger than 28 weeks' gestation. Aqueous CHG has generally been found to be safe. [40,55] There is a single report of skin reactions to 2 percent aqueous CHG when used prior to catheter insertion in four neonates younger than 26 weeks' gestation who were also less than 48 hours old. [148,149] For such infants, special attention must be taken to avoid excessive skin exposure, remove excess CHG with sterile gauze, and take care to prevent pooling of the antiseptic under the infant. Povidone-iodine has been used for skin disinfection for CVC insertion and care, but is not a safer option for premature newborns as it may result in iodine absorption and thyroid dysfunction. [55]

Use of a CHG-impregnated sponge CVC dressing reduced the rate of CVC catheter colonization in neonates. Local skin reactions occurred in some infants of gestational age younger than 26 weeks who were also less than 7 days old, precluding use of the dressing for young LBW infants. [60] If these dressings are used, careful monitoring of skin condition is warranted and removal of the sponge is necessary if skin irritation develops. CVCs coated with antiseptic or antibiotic reduce the risk of infection but have not been evaluated adequately in neonates and have limited availability in smaller catheters.

The use of umbilical vessel catheters is unique to the initial management of the ill newborn. This nonsterile insertion site increases the risk of catheter colonization. Umbilical arterial catheters should be

removed within 5 days, and venous catheters should be removed within 14 days of insertion. [60]

Central Nervous System Infections

Meningitis occurs in up to 25 percent of infants with early-onset BSI. [69,84] GBS and *E. coli* are the predominant causes. Gram-negative bacilli are the major causes of nursery-acquired meningitis. [7,102,138] *C. diversus* of maternal or nursery origin may cause meningitis with focal brain lesions. Nursery-acquired central nervous system (CNS) infections with *Listeria*, group A streptococcus, *S. aureus*, *Campylobacter fetus*, and *Campylobacter jejuni (C. jejuni)* have been reported. [84]

Neural tube defects [84]and ventricular drains and shunts are risk factors for CNS infection. CoNS is the major cause of shunt infection. [84] The role of perioperative antibiotic prophylaxis in the newborn has not been established, but preoperative antiseptic bathing and use of intraoperative topical antiseptics may be beneficial. Use of maximum sterile barrier precautions (cap, surgical mask, sterile gown, sterile gloves, and sterile drapes) and antiseptic skin preparation prior to surgical procedures involving the CNS can prevent transfer of microorganisms. Lumbar punctures and shunt taps are routinely performed at bedsides in NICUs. Measures such as strict hand hygiene, skin preparation with antiseptic, use of sterile barrier precautions (especially sterile gloves and face mask [17]), safe injection practices, and traffic control may help reduce the risk of infection acquired from microorganism contamination during procedures that involve placing a catheter or injecting material into the spinal or epidural space. [17]

Neonates with meningitis are frequently indistinguishable from those with sepsis. Convulsions, bulging fontanel, and signs of meningeal irritation are uncommon until infection is advanced. All newborns suspected of having sepsis should have a lumbar puncture performed to assess for meningitis, because it is impossible to rule out CNS involvement by clinical examination, and blood cultures may be negative in one third of the cases. [84] If the clinical condition precludes lumbar puncture before antibiotic therapy is initiated, CSF should be obtained as soon as the infant’s condition is clinically stable. CSF pleocytosis in an infant with a positive blood culture is presumptive of CNS infection, especially if antibiotics have been administered prior to lumbar puncture. Empiric treatment is as for BSI, using antibiotics known to penetrate the CNS. Infections related to shunts or drains usually require device removal. [84]

Pneumonia

Early-onset pneumonia is usually associated with intrapartum infection and early-onset sepsis. Pneumonia is the second most common HAI in NICUs and most cases are ventilator-associated. [1] Endotracheal intubation and LBW have been shown to be a risk factor in the development of healthcare-associated pneumonia. This may be caused by the correlation between LBW and the prolonged use of mechanical ventilation. Both a history of prior BSIs and NICU crowding have been identified as risk factors. [1] VAP may be difficult to diagnose in this population and NHSN definitions may not be uniformly applied. Exposure to contaminated resuscitation and respiratory therapy equipment has been associated with outbreaks of infection with Gram-negative microorganisms. Respiratory viruses also may cause healthcare-associated pneumonia. [150,151]

Clinical features include respiratory deterioration with dyspnea, apnea, and cyanosis, and increased need for oxygen and ventilator support. Diagnosis of pneumonia is difficult because many noninfectious conditions can cause respiratory deterioration; underlying lung disease complicates interpretation of radiographic changes; and procedures such as bronchoscopy and lung biopsy are rarely performed in newborns. Infants are frequently treated empirically for presumed lung infection without confirmation of the diagnosis. Except for viral pneumonia, specific microbiological diagnosis is rarely obtained unless there is associated BSI. Endotracheal cultures can be useful in determining the cause of perinatal pneumonia. Such cultures are not helpful in diagnosing pneumonia or determining the specific cause since the respiratory tract of the intubated newborn rapidly becomes colonized. Treatment of early-onset infection of maternal origin is the same as for neonatal BSI. For late-onset infection of nursery origin, treatment is empirical with broad-spectrum antibiotic therapy directed against organisms known to be endemic in the particular NICU. [5,151,152,153]

Prevention includes use of appropriate techniques in suctioning and handling of the endotracheal tube, maintenance of respiratory therapy equipment, and prevention of exposure to respiratory viruses. [2,3] A study comparing closed suction systems with open systems for neonates showed no difference in incidence of VAP, BSI, or mortality. [3,151]

Recent advances in respiratory management have reduced the time many newborns are ventilated and, in some cases, have eliminated the need for mechanical ventilation. [152] VAP bundles used in the adult population are being evaluated in neonatal care. Improved endotracheal tube care, oral care, and handling of respiratory equipment, along with advances in minimally invasive respiratory support, lower the risk of pathogens entering the respiratory tract. [5,150,151]

Gastrointestinal Infections

Gastroenteritis occurs in the newborn nursery, SCN, and NICU. Infection can be acquired during delivery or during neonatal care. In outbreaks, the index case may have infection of maternal origin, with subsequent transmission by way of contaminated hands or equipment. Infected personnel have rarely been involved. [90]

Rotavirus is the most common cause of healthcare-associated diarrhea in developed countries. In developing countries, outbreaks of diarrhea caused by *Salmonella* and pathogenic strains of *E. coli* occur frequently. [90] *Salmonella* outbreaks are sometimes recognized late because of delayed onset of symptoms and prolonged shedding by the newborn. [90] Outbreaks of enteropathogenic *E. coli* infection can progress rapidly with symptomatic infection of most newborns at risk. Sometimes progression is more indolent with limited clinical infections but many carriers. Although *Shigella* spreads very rapidly among older children, symptomatic infection and transmission among newborns is unusual. [90] Transmission to nursery personnel has been reported. *C. jejuni* infections occur occasionally and origin may be maternal or related to neonatal care. [90]

Clinical features include vomiting, diarrhea, and abdominal distention. Bacteremia can occur, especially with *Salmonella* or *Campylobacter* infections. Diagnosis is by isolation of the pathogen in culture or detection of rotavirus antigen or nucleic acid in stool. Treatment is supportive but antibiotic therapy is indicated if concomitant bacteremia is suspected. Newborns with *Salmonella* gastroenteritis should

receive parenteral antibiotic therapy due to the high risk of invasive disease and bacteremia. [90]

Prevention includes contact precautions for infants with diarrhea and care in the preparation and administration of infant feedings.

Necrotizing Enterocolitis

NEC is the result of injury to the immature gastrointestinal tract. Prematurity, ischemia, overgrowth of gastrointestinal bacteria, bacterial toxins, and local production of inflammatory mediators are contributing factors. NEC occurs in 10 to 15 percent of VLBW infants, but term infants also may be affected. [94]

Although infection may not be the primary process, NEC is considered to be an HAI by NHSN. [16] Cases frequently occur in clusters. Several different organisms, including *Klebsiella*, *Clostridium*, *E. coli*, *Serratia*, *Pseudomonas*, CoNS, and enteric pathogens such as *Salmonella*, toxigenic *E. coli*, and *S. aureus* have been associated with outbreaks of NEC. [90] Whether *C. difficile* toxin plays a role is controversial. Rotavirus has been associated with outbreaks of a mild form of NEC. It is probable that any microbe capable of damaging immature gastrointestinal mucosa can contribute to this disease. Organisms isolated from blood and peritoneal fluids are those that have invaded through the damaged mucosa and are not necessarily the primary cause of the disease. [94]

Infant signs and symptoms for NEC include prefeeding residuals, vomiting, abdominal distention, and blood in the stools, along with general features of sepsis. NEC is diagnosed by clinical and radiological criteria. The NHSN definition for surveillance purposes requires that each of the following three criteria be met: (1) at least two of vomiting, abdominal distention, or prefeeding residuals, without other recognized cause; (2) persistent blood in the stools on microscopic or gross examination; and (3) at least one of the following radiographical abnormalities: pneumoperitoneum, pneumatosis intestinalis, or unchanging “rigid” loops of the small bowel. [16]

Blood cultures should be obtained. Cultures of intra-abdominal sites should be included if peritoneal drainage or surgery is performed. Therapy consists of discontinuation of oral feeding, parenteral nutrition, gastric decompression, empiric antibiotics directed against suspected gastrointestinal flora, and surgery if perforation is suspected. [94] Prophylactic oral vancomycin has been used to protect VLBW infants against NEC; routine use is not recommended due to risk of colonization with vancomycin-resistant organisms. Breast milk is protective. [56,90] Administration of oral immunoglobulin containing IgA and IgG was protective for LBW infants in one study. Neonates fed Lactobacillus and Bifidobacterium had a reduced incidence of NEC when compared with historical controls. [94]

Urinary Tract Infection

Neonatal UTI occurs in approximately 0.5 to 1 percent of term infants and 1.9 to 2.9 percent of high-risk and premature infants. [69] HAIs in neonates are often unrelated to instrumentation. In one pediatric study, the rate of healthcare-associated UTI in the NICU was 1.9 per 100 admissions, with only 17 percent catheter related. Urinary catheters are not commonly used in newborns, but when they are used, the infection rate is higher than in older children. *E. coli* is the most common etiology. Other organisms frequently isolated include *Enterococcus*, *Pseudomonas*, *Klebsiella*, CoNS, and *Candida*. [69]

Infants frequently present with nonspecific signs of sepsis. Diagnosis is by culture of urine obtained by sterile catheterization or bladder puncture. Yield from urine culture is usually low during the first week of life and may provide limited source information. In contrast, urine culture should be collected before initiation of treatment if late onset sepsis is suspected. Blood cultures should be obtained in all neonates suspected of having UTI. [55,84] Infants with Candida UTI should be evaluated for renal fungus balls. [154]

Empiric treatment for UTI is the same as for neonatal sepsis, and is adjusted once the specific cause has been identified. [84] Prevention involves limiting the use of urinary catheters to essential situations. [55]

Surgical Site Infection

Several reports indicate that neonates are at elevated risk for SSIs. Data on the efficacy of antibiotic prophylaxis for surgical procedures in the newborn are limited, and there are no precise pediatric guidelines; however, adult principles of antimicrobial agent selection and exposure at the surgical site should apply to children. [152,153] AAP identifies surgical body cavity exploration in neonates as a situation in which prophylaxis for clean surgical site procedures may be justified. [153]

Patients cared for in the NICU frequently require surgical procedures. The risk of hypothermia changes in hemodynamic status, and the dislodgement of catheters and tubes create challenges in transport to an operating room. Minor procedures are usually performed at the patient’s bedside. More extensive emergent surgeries (e.g., patent ductus arteriosus ligation), where transport associated risk is too great, must be performed in a NICU area that is separate from other neonates. This area must have adequate lighting, monitoring equipment, and the appropriate surgical personnel. Operating room attire should be worn by all personnel attending the procedure. [15] Ventilation in the area should follow recommendations for positive pressure environment and appropriate air exchanges established for the surgical suite. [155]

Skin, Subcutaneous, and Mucosal Infections

Normal newborns, as well as those in the NICU, can develop infections of the skin, mouth, and eyes. [68, 69,94] Usually these are benign superficial infections. Pustules, cellulitis, subcutaneous abscesses, lymphadenitis, and infections at sites of percutaneous punctures are most often caused by *S. aureus*. [94]

Maternal genital microorganisms can cause infections at scalp monitor sites. These include HSV, *Mycoplasma hominis*, and *Gardnerella*. *Candida* infections of the skin and mouth are frequent in infants in the NICU. [69,94]

Omphalitis has been reported in 0.5 percent of term and 2 percent of preterm infants, with infection varying from mild erythema or serous drainage to purulent discharge, cellulitis, and acute necrotizing fasciitis of the abdominal wall. *S. aureus* is the most frequent etiology. [94] Group A streptococcus, CoNS, enterococci, Gram-negative rods, and anaerobes also may be involved. CaMRSA is commonly identified with skin and soft tissue infection in the neonate. Most of these infections are minor but may develop into invasive disease, bacteremia, and death. [71,94] Neonatal tetanus from umbilical infection occurs in areas where conditions of delivery and cord care are not hygienic and mothers are not immunized. [94]

The rate of infection after neonatal circumcision is low, at 0.06 to 0.4 percent, and most infections are minor wound infections; however, bullous impetigo, staphylococcal scalded skin syndrome, and necrotizing fasciitis have been reported. [94] Circumcision infections are classified with skin and soft tissue infections and not with surgical site infections in NHSN surveillance. [16]

Infectious conjunctivitis in the newborn is usually caused by Chlamydia or gonococcus of maternal origin and presents after discharge from hospital. [94] *S. aureus* conjunctivitis is also common, and outbreaks occur in the newborn nursery, SCN, and NICU. In the NICU, conjunctivitis is frequently seen in outbreaks of *Serratia* infection. *P. aeruginosa* conjunctivitis has been associated with contaminated resuscitation equipment and with eye contamination by endotracheal tube secretions during suctioning. *P. aeruginosa* eye infection in premature infants can progress rapidly to the destruction of the cornea, invasion of the eye, and secondary bacteremia. Adenoviral conjunctivitis has been associated with ophthalmological examination. [94]

Prevention and Control of Infections

Current infection prevention strategies reduce transmission of microorganisms among infants in the nursery by: emphasizing hand hygiene before and after contact with each infant; not sharing equipment and supplies between infants; and preventing the acquisition of infection from contaminated feedings, water, air, or infected healthcare personnel and visitors. Judicious use of invasive procedures and adherence to aseptic technique will minimize the risk of infection from the infant's endogenous flora.

Infection prevention strategies have been shown to reduce NICU HAI rates. [1,2,3,5,6] Implementation of guidelines standardizing care and utilizing best practices has been shown to decrease rates of bacteremia. [6,11,31,34]

Infection Prevention in Nursery Design and Construction

The nursery should be located in a low traffic area with restricted access. [155] The design should provide adequate space for appropriate care of the infant and for the necessary patient care equipment. [19,155] Current recommendations from AAP in collaboration with the American College of Obstetricians and Gynecologists (ACOG) [5,19] include the following floor space requirements for multipatient rooms: for newborn nursery, 24 net feet^2 per infant and at least 3 feet between bassinets; for SCN and NICU, at least 120 net feet^2 per infant and at least 8 feet between incubator, warmer, bassinet or crib, with aisles at least 4 feet wide. Floor space allocations are greater for single patient rooms: for SCN, at least 150 net feet^2; for NICU, at least 150 net feet^2 and 8-foot wide aisles. Space should be added for sinks, desks, cabinets, computers, and corridors. There should be sufficient numbers of strategically placed sinks for hand hygiene. [19,155] AAP-ACOG recommends one sink for every six to eight patients in the newborn nursery and one sink for every three to four patients in SCN and NICU. [19] There should be a sink in the resuscitation area and one sink per three to four patients in admission, observation, and continuing care areas. [19] Air supply for the NICU should undergo filtration of at least 90 percent efficiency, and be positive air pressure to adjacent areas. [19,154] Guidelines from AAP-ACOG and the Facility Guidelines Institute recommend a minimum of six air exchanges per hour. [19,155] The nursery

should have access to at least one airborne infection isolation room to accommodate newborns with airborne infections. This room could be located on another unit if necessary. [5,155]

Newborns and patient care equipment should be protected from exposure to dust and debris during any maintenance, construction, or other dust-generating activities, including breaking into or drilling holes in walls or ceilings, sanding, or removal of ceiling tiles. An infection control risk assessment should be completed before work begins. [155,156] Renovation procedures in the NICU require maximum barriers and protection of the ventilation system. Impermeable barriers should be set up to prevent air from the construction zone entering the nursery or the ventilation system. If this is not possible, newborns should be moved to a separate hospital area. [155,156] Communication between building contractors and NICU charge personnel is recommended to ensure smooth renovation activities and to prepare for unplanned problems during the process. Thorough cleaning procedures should follow all maintenance and renovation activities. [155,156]

Surfaces should be designed to be water-resistant near plumbing fixtures. Water leaks should be reported immediately. Areas of water damage not addressed within 48 hours may need replacement. Hard surfaces may be disinfected with bleach. [156]

Infection Prevention and Nursery Staffing

There should be sufficient numbers of staff to permit time for adequate care of the infants and hand cleansing between patient contacts. AAP-ACOG recommend one neonatal registered nurse for every six to eight infants in the newborn nursery, one nurse for every three to four patients requiring intermediate care in SCN, and one nurse for every one to two patients in the NICU. [19]

Infection Prevention in Routine Newborn Care

Umbilical Cord Care

Procedures for cord care vary. No single method of cord care has proved to be superior. [55] The Cochrane Database published a systematic review of 21 studies of cord care including 8,959 participants, the majority of which were from high-income countries. [157] No systemic infections or deaths were observed in any of the studies. Cord treatment with antiseptics versus antibiotics, dry cord care, or placebo yielded no significant differences in results. There was a trend toward reduced colonization with the use of topical antibiotics compared with topical antiseptics. Antiseptics tended to prolong the time to cord separation. Natural cord drying is recommended with focus on keeping clean and dry. The routine use of topical antiseptics (isopropyl alcohol, povidone-iodine, topical antibacterial agents, triple dye, or CHG) showed no benefit in reducing omphalitis in developed countries; however, they may be beneficial in low-resource settings. It is important to distinguish normal cord healing from potential infections. [55,158,159]

Skin Care

Maternal blood and meconium should be removed with sterile cotton sponges and warm water. Heat loss should be minimized to ensure temperature stability. Because of potential exposure to bloodborne viruses, personnel should implement Contact Precautions and wear gloves with all handling of the neonate until the initial skin cleansing has been performed. After this, cleaning of the diaper area and other soiled areas using warm water with or without a mild soap is sufficient throughout the nursery stay. When soap is used, it should be supplied in a single-use container or reserved for use with one infant. [5,55]

Bathing with an antiseptic agent is not recommended for routine newborn care, but is indicated in an outbreak if the benefit outweighs the potential risk of toxicity. CHG has been useful in outbreak control. No significant toxicity has been reported, and cutaneous absorption is negligible. [55] Use of iodophors in neonates may result in the absorption of iodine. Triclosan has been used to bathe neonates, but there is as yet little information about safety and efficacy. [40] Any agent used should be provided in containers reserved for use with an individual infant.

Damage to the newborn skin by excessive drying, manipulation, or other trauma should be minimized. Minor trauma to the skin of the premature newborn, such as may occur with removal of adhesive tapes or oxygen probes, can damage the outer layer of the epidermis. [55,158] A meta-analysis indicated that the prophylactic use of topical emollient ointment in extremely premature infants improved skin condition but increased the risk of CoNS infection. However, the criteria used to define CoNS infection were imprecise. [160] Ointments readily become contaminated and, if used, should be provided in unit dose containers. [55]

Eye (Conjunctival) Care

At delivery, the eyes of the neonate should be cleaned with sterile cotton to remove secretions and debris. Topical prophylaxis against neonatal eye infection (gonococcal ophthalmia neonatorum) should be administered within 1 hour of birth or immediately after the initial breastfeeding in the delivery room. Application of 1-cm ribbon of sterile ophthalmic ointment containing 0.5 percent erythromycin or 1 percent tetracycline ointment is appropriate; ensuring that all parts of the conjunctival sac are covered. Single dose containers should be used. Solutions of 1 percent silver nitrate are an alternative but are associated with a 10 to 20 percent incidence of chemical conjunctivitis. [55,56,152,153]

Care should be taken to avoid contamination of the eyes with respiratory tract secretions during suctioning of the nasopharynx or endotracheal tube. [55]

Infant Feeding

Breast milk provides immunological as well as nutritional benefits and is reported to reduce the risk of sepsis in premature infants. If expression of breast milk is necessary because the ill infant is unable to suck, measures should be taken to minimize bacterial contamination. These include antiseptic hand hygiene and expression of milk into sterile containers. If a breast pump is used, all pump components that are in contact with milk should be washed with hot soapy water after each use, dried thoroughly, and stored in a clean place. Pump components should be sterilized or disinfected between uses by different mothers and daily if used by only one mother. Optimal breast milk storage guidelines are based

on location of storage and associated temperature. Storage duration for room temperature (16 to 29°C [60 to 85°F]) is 3 to 4 hours; refrigerator (4°C [39°F] or below) is 72 hours; freezer (below 17°C [0°F]) is optimal up to 6 months and acceptable up to 12 months. Sterile containers free of bisphenol A are recommended for storage. Frozen breast milk may be thawed in the refrigerator or quickly under running water with care to avoid contamination from the water. Milk should not be subjected to excessive heat from hot water or a microwave oven. After thawing, milk should be used promptly or stored in the refrigerator for no longer than 24 hours. Once the milk is removed from the refrigerator, feeding should be completed within a maximum of 4 hours. Microbiological testing of expressed milk is rarely indicated, but may be considered if neonatal gastrointestinal intolerance or sepsis is suspected. Expressed milk usually contains normal skin microorganisms. Presence of Gram-negative bacilli suggests contamination during collection or handling. [19,51,54,55,56]

If breast milk is stored in hospital, protocols should be established to ensure proper identification of the milk to prevent infants inadvertently being fed milk from mothers other than their own. A written policy should be in place for management and follow-up of such events, which could result in transmission of bloodborne viruses. [51,53,55]

If formula feeds are required, most nurseries in North America use sterile commercial formula prepared ready to feed. Bottles should be used within 4 hours of uncapping. [55] Commercial liquid concentrates are sterile. Commercial powdered formulas are not sterile and should be used only if there is no alternative. [52,55] Formula made from liquid concentrates or powders must be prepared using aseptic techniques. Water used for dilution or reconstitution should be sterile, and equipment should undergo sterilization or disinfection before use. Blenders are not recommended. [54,55,144] If used, blenders should be thoroughly cleaned after each use and sterilized daily. Formula should be bottled in quantities required for individual feeds or for 4 hours of continuous feeding, should be stored refrigerated for a maximum of 24 hours, and should be used within 4 hours of opening. [52,55] Routine microbiological testing is not recommended but may be indicated if the formula is suspected to be implicated in infection.

Bacteria can multiply to high levels in small-volume feeds held at room temperature. Hang time for formula and breast milk should be limited to 4 hours or less. Replace the entire feeding setup every 4 hours. Topping off of formula or breast milk containers should not be done. [55]

Processing of formula and breast milk should be avoided whenever possible in the nursery area. [55] Formula rooms are strongly recommended for the NICU. These rooms allow preparation of infant formula in an aseptic environment, away from the bedside potentially crowded with contaminated specimens and equipment. Formula rooms are more commonly found in pediatric hospitals but are important for the aseptic preparation of the sometimes-complicated formulas required for preterm infants. Breast milk preparation rooms are also recommended but less commonly available. These rooms are designed to aseptically prepare, store, and fortify expressed mothers' milk in a specialized location. If feeds must be prepared in the nursery, care should be taken to do so aseptically in a designated clean area of the nursery. [5,15,55]

Administration of fresh, unscreened donor milk is not recommended because of concerns over transmission of infection. [55] Milk donors require careful screening for ability to carry out aseptic technique, evidence of acute or chronic infection, use of drugs and medications, and other factors that

might impair the quality of their milk. [51,55] The Human Milk Banking Association of North America recommends that donors have negative serology for HBV surface antigen (HBsAg), HCV, HIV-1, HIV-2, HTLV-I, HTLV-II, and syphilis. [51] Donors also should be assessed for active, untreated TB. [55] Screening for CMV should be considered but is not necessary if milk is heated to 62.5°C for 30 minutes. [51] Aseptic techniques should be used during milk collection and processing, and all donor milk should be pasteurized at 56° or 62.5°C for 30 minutes to inactivate bacteria and bloodborne viruses. [51,55] After pasteurization, appropriate care must be taken to prevent contamination during handling. Donor milk should be used only if bacterial cultures are negative. [51]

Reduction of Risks Associated with Invasive Procedures and Devices

Technological advancements in neonatal care often involve the introduction of new invasive procedures or devices. When this occurs, the potential risk for HAI should be assessed, protocols should be established to minimize risk, and surveillance should be set up to monitor for infection. The need for an invasive device should be reassessed daily, and use should be discontinued promptly when it is no longer essential.

Infection prevention strategies for prevention of infections associated with intravascular catheters, endotracheal tubes, urinary catheters, dialysis catheters, and ventricular drains in the newborn are not different from those used in other patients and are addressed elsewhere (see **Chapters 33 Urinary Tract Infection**; **34 Intravascular Device Infections**; **39 Dialysis**; and **55 Endoscopy**). Prevention of infections associated with intravascular catheters is discussed in the preceding text under Sites of Infections: Bloodstream Infections.

Safe injection practices are recommended. These include use of single-dose vials rather than multidose vials, especially when medication will be administered to multiple patients. If multidose vials must be used, unit doses should be withdrawn using meticulous aseptic technique, preferably in the pharmacy. Avoid transferring medications from one container to another for ease of administration, as bacterial contamination may occur. [17,42]

Reduction of Risk from Blood Transfusions

Blood products should be used with caution and with consideration of risks and benefits. In many countries, blood donors are routinely screened for HBV, HCV, HIV-1, HIV-2, HTLV-I, HTLV-II, and syphilis. Cellular blood components for LBW infants should be obtained from CMV-seronegative donors or treated to remove CMV. If CMV-negative or -depleted blood is not used routinely for larger newborns, it should be considered for seronegative newborns receiving large volumes of blood or any neonate with increased risk of developing CMV disease. [51] Directed blood donations from parents should be screened for bloodborne pathogens in the same manner as is routine for all donated blood. The decision to use parental CMV-seropositive blood should consider the gestational age of the newborn. [51,55]

Prevention of Transmission of Microorganisms from Newborns: Routine Procedures

Current guidelines for isolation precautions recommend certain basic practices for the care of all patients. These practices are referred to as Standard Precautions, [17] with the goal of reducing transmission of microorganisms from all patients, including those with unrecognized infection or colonization. Routine newborn care procedures designed to prevent acquisition of abnormal flora prevent the transmission of most infections among newborns.

Hand Hygiene

Hand hygiene is an important means of preventing infection, yet it is difficult to monitor or enforce. Studies show poor compliance with this procedure in the NICU. [3,27,37] Each hospital should establish and enforce a hand hygiene policy for all persons entering the nursery. Jewelry should not be worn on hands or wrists because it interferes with effective hand hygiene. Nails should be trimmed short, and no false fingernails should be worn. [5,40] It is recommended that personnel wash their hands and arms to above the elbows, with care to clean all parts of the hands and beneath the nails, before handling neonates for the first time on a work shift. The optimal duration of hand hygiene has not been established, but sufficient time should be taken to thoroughly wash and rinse all parts of the hands. [5] Performance of a prolonged scrub on entry to the nursery is likely to be of less benefit than careful hand hygiene between patients. Hand hygiene should be performed before and after each patient contact and after contact with potentially contaminated patient care equipment. [5,40]

An antiseptic agent is recommended. [5,40] Alcohol-based antiseptic hand rinses are now considered the preferred option for hand hygiene. These are at least as effective as water-based antiseptic soaps and are better tolerated and more convenient to use. [3,40,146,161] Routine use of alcohol-based hand rinses has been associated with improved hand hygiene compliance [161,162] and decreased HAI rates; products have been useful in outbreak control. Hand rinses are less effective on soiled hands. [40] An antiseptic soap should be used for hand washing when hands are visibly soiled or after caring for patients with infections caused by organisms resistant to alcohol-based antiseptics, such as *C. difficile,* norovirus, or anthrax. CHG is the agent most often used. [5,40] CHG has the advantage of leaving a residual antibacterial effect on the skin and is less irritating than iodophors.

In an effort to increase hand hygiene, audit programs have emerged to track compliance of hand hygiene efforts of healthcare personnel. Capretti et al. identified a drop in incidence of HAIs in VLBW infants in the NICU with improved compliance. The efforts were found to be associated with cost effectiveness. [163]

Gowns

AAP-ACOG recommends that a long-sleeved gown be worn by personnel holding a newborn outside of the bassinet or incubator. [5] A separate gown should be used for each infant and discarded after use or maintained exclusively for the care of a single infant and changed at the end of a shift or if wet or soiled. Long-sleeved gowns also should be worn to protect uncovered skin during procedures and activities that may result in skin exposure to blood, body fluids, secretions, or excretions. [17]

Several studies have shown that routine use of gowns does not reduce colonization or infection rates in the normal newborn nursery or the NICU. A systematic review of the studies conducted regarding the practice of wearing cover gowns when handling infants in the newborn nursery and NICU showed there is no evidence to support the use of gowning by staff to prevent the spread of infection. [164]

Gloves

Gloves should be worn when touching mucous membranes or nonintact skin and for contact with blood, body fluids, secretions, excretions, and items contaminated with these substances. Gloves should be removed promptly after use and before contact with another patient; hands should be washed when gloves are removed. [17] Gloving is not mandatory for routine infant wet diaper changes if this procedure can be done without direct hand contact with urine. [51]

Masks and Protective Eyewear

Masks and goggles or glasses should be worn to protect the mucous membranes of healthcare personnel during procedures that may generate splashes or sprays of blood, body fluids, secretions, or excretions. [17]

Disinfection of Equipment between Patients

All equipment should be cleaned and disinfected between patients. Equipment in direct contact with the skin or mucous membranes of newborns should be sterilized or undergo decontamination with a high-level disinfectant. [87] Examination equipment, such as stethoscopes and ophthalmoscopes, should be reserved for use with one patient or decontaminated with alcohol or other disinfectant approved for this equipment. Toys should be reserved for the use of one patient unless they can be sterilized for neonatal use. Equipment that is not in direct contact with skin or mucous membranes should be cleaned with a hospital-grade disinfectant-detergent. [5] Phenolics should be used with caution. [97] For additional information on cleaning, disinfection, and sterilization, please see **Chapter 31 Cleaning, Disinfection, and Sterilization**.

Prevention of Transmission from Newborns with Recognized Infection

Transmission-based Precautions

Transmission-based and additional Precautions are recommended for certain clinical conditions and infectious agents, based on the method of transmission (airborne, droplet, or contact). [17,51] Isolation strategies in the nursery are determined by the mode of transmission of the pathogen involved, number of infected or colonized newborns present, and level of care required by those newborns. Most infections in newborns arise from endogenous flora, and additional isolation precautions are not indicated. Single rooms are recommended for neonates with infections requiring Transmission-based Precautions, but may not be feasible for the care of an ill neonate. The major route of transmission of infection among patients in the nursery is indirect contact. Newborns are not mobile, so transmission among patients by direct contact should not occur. An exceptional circumstance with potential for direct transmission is cobedding of siblings. Neonates do not cause heavy contamination of their environments, and they are inefficient producers of respiratory droplets. It is not necessary to place a newborn requiring Transmission-based Precautions in a single room if:

1. The infection is not airborne.

2. There are adequate numbers of nursing and medical personnel with sufficient time for appropriate hand hygiene.
3. There is sufficient space for a 4- to 6-foot area between newborn stations and minimum of 8 feet for NICU and SCN.
4. There is an adequate number of sinks for hand hygiene.
5. Continuing instruction is given to personnel about the mode of transmission of infections. [5]

A single room with negative pressure ventilation (airborne infection isolation room) is required for infections transmitted by the airborne route, such as varicella, measles, and TB. The asymptomatic infant of a mother with peripartum varicella or measles requires similar isolation. These infections are rare in the nursery. Infants are unlikely to transmit TB by coughing, but infectious aerosols can be generated during suctioning. Tuberculin skin test conversions have occurred in healthcare personnel exposed to neonates with unrecognized TB. All personnel who enter the room of a patient with TB and nonimmune personnel who must enter the room of a patient with varicella or measles should wear N95 respirators. Forced-air incubators cannot be substituted for negative-pressure rooms because they discharge unfiltered air into the nursery. [5] Airborne Precautions were used along with Contact Precautions and eye protection by personnel caring for infants born to mothers with severe acute respiratory syndrome (SARS) in the 2003 outbreak in Hong Kong. [165]

For other infections where air control is not necessary, an isolation area can be defined in the nursery by curtains, partitions, or other markers. A closed incubator can be helpful, but surfaces and entry ports readily become contaminated by hands. The outside of the incubator should always be considered contaminated, and the boundaries of the isolation area should extend beyond the incubator itself. In the newborn nursery, the most feasible strategy is isolation of the occasional newborn with gastroenteritis, respiratory tract infection, or skin infection in a single room or to have the infant room in with the mother. When multiple cases of infection occur, as is common during community outbreaks of viral infection, cohorting in a multipatient nursery is a more feasible option. [5]

Gloves and gowns are recommended during the care of patients requiring Contact Precautions. All equipment and others items brought into the patient's area must be disinfected before use with another patient.

Current guidelines indicate that infants requiring Droplet Precautions should be separated from other patients by at least 3 feet and personnel within 3 feet of the infected infant should wear surgical masks. Research performed during the SARS outbreak suggested droplets may have traveled as far as 6 feet from the source patient. [165] Distance traveled by droplets depends on factors such as size of droplet as well as velocity. Although newborns do not cough forcefully and are unlikely to propel respiratory droplets outside of their immediate area, endotracheal suctioning and mechanical ventilation may propel droplets over larger distances. The CDC suggests that it may be prudent to maintain a 6-foot distance between patients and don a mask if within 6 feet of the patient. Care should be taken to evaluate each situation on a case-by-case basis with consideration of potential pathogen in question. [17,166] Most respiratory viral infections are spread by contact as well as droplet routes. Personnel should take care to prevent inoculation of their eyes or nose with infectious respiratory secretions that have contaminated their hands. Gloves reduce the risk of accidental inoculation. Masks alone are of limited value, but face shields or goggles with masks reduce transmission.

Surveillance Cultures

Performing routine surveillance cultures was previously not recommended, due to poor correlation of isolates between surveillance cultures and those related to invasive infections. Review of isolates causing invasive disease in nursery patients is a better process to identify trends in prevalence of infecting microorganisms to help guide empiric antibiotic therapy.

Recommendations for routine use of surveillance cultures targeting specific antimicrobial-resistant pathogens have increased recently. Surveillance cultures may be useful in identifying colonization of infants for implementation of Transmission-based Precautions to reduce transmission of these organisms in a closed environment (e.g., newborn nursery, SCN, or NICU). Efforts to reduce transmission of VRE and MRSA have been successful using these procedures in addition to physical separation of infected and colonized patients from other patients and the use of appropriate hand hygiene. [74,78] The usefulness of active surveillance cultures in outbreaks has been established. Active surveillance culturing has also been helpful and cost-effective in screening patients in a high-risk environment in the absence of an outbreak. This may be accomplished by screening for a specific organism upon admission to the unit. Each institution may decide to use this technology depending on the individual needs, requirements, and patient populations. The use of active surveillance culturing is expensive and time consuming for the laboratory, NICU, and infection prevention department. [78]

Outbreak Management

An outbreak investigation should be undertaken when there is a significant increase in the rate of infection at a certain body site or with a particular microbe. This involves the identification of the microorganisms involved, possible reservoirs, and common risk factors for transmission or acquisition of infection. A review of infection prevention procedures, including compliance with hand hygiene, aseptic techniques, and practices for sterilization and disinfection, should be performed. Frequently, this review has ended an outbreak before, or without, the identification of a specific source of infection or problem in procedure. [5]

Increased infection rates involving a number of different microbes or strains of the same microbe are likely to indicate breakdown in infection prevention procedures seen with crowding, understaffing, major disruption of routine functioning of the unit, defective sterilization or disinfection technique, or a change in the use of invasive devices and procedures.

An increase in infections because of a single microbe suggests a common-source outbreak or the introduction of a virulent strain into the nursery. Surveillance cultures may be useful to identify the extent of colonization and assess the risk factors for acquisition. [5] Microorganisms endemic in nursery populations, such as CoNS, *E. coli*, or *Candida*, may require typing by molecular techniques to determine whether one or several strains are involved. Infected or colonized patients should be rapidly identified and either isolated or cohorted. If such identification is not possible, separate cohorts should consist of infants who are symptomatic, asymptomatic but exposed, or not exposed. Cohorts should be accommodated in separate rooms or clearly identified areas of a large room. [5] Cohorting of personnel may be considered, but the efficacy has not been determined. Cohorting may be counterproductive if it results in understaffing or undue disruption of nursery routine. Cultures of potential environmental sources or personnel should be obtained only if preliminary epidemiological investigation suggests an association with infection. [5] Surveillance for infection may need to be extended to recently discharged infants, especially in newborn nurseries, where discharge may occur during the incubation period.

Cohorts should be maintained until all infected and exposed infants are discharged or the expected period of pathogen shedding has passed. If an outbreak is not brought under control by these measures, the unit should be closed to new admissions until all infected and exposed infants have been discharged.

Prevention of Transmission from the Mother with Infection

Transmission of infection from mother to newborn usually occurs during delivery, and postpartum separation of mother and newborn is rarely indicated. Most maternal postpartum infections are urinary or gynecological, caused by endogenous flora, and not transmissible with basic hygienic measures. A mother with a communicable infection should wash her hands before handling her infant and take measures to prevent contact between the infant and potentially contaminated clothing, bedclothes, tissues, and other fomites. Abscesses, draining wounds, and cutaneous HSV lesions should be covered. [5] CDC guidelines suggest that a mother with influenza should wear a surgical mask while breastfeeding and when within 3 feet of her newborn. [167]

A mother with untreated active pulmonary TB should be separated from her newborn until she is considered noninfectious. The newborn of a mother with varicella may remain with her once the infant has received VZIG. [138] A mother with group A streptococcus infection should be separated until appropriate antibiotic therapy has been started and the infection is no longer considered communicable. [5] Separation also should be considered if a mother has extensive *S. aureus* infection with drainage that cannot be contained by dressings. In the 2003 outbreak in Hong Kong, mothers with SARS were separated from their newborns. There were no transmissions from mother to newborn. [165]

Breastfeeding by an infected mother is rarely dangerous for her infant. [51,55] Maternal HIV infection is a contraindication to breastfeeding, as is maternal seropositivity to HTLV-I. AAP recommends that women who are HTLV-II seropositive also be advised not to breastfeed, pending further knowledge about transmission of this virus. Transmission of HBV or HCV by breast milk has not been documented, and breastfeeding by infected mothers is not contraindicated. [51] Decisions concerning breastfeeding of premature infants by CMV seronegative mothers with primary CMV infection, and of VLBW infants by CMV seropositive mothers, should take into consideration the potential risks and benefits. Pasteurization of breast milk may be advisable. [51,55] Mothers with HSV lesions around the nipples should not breastfeed until the lesions have resolved. A mother with active untreated TB should not breastfeed until she has received adequate antimicrobial therapy. Breastfeeding is not contraindicated for mothers on antibiotic therapy for simple mastitis, but is contraindicated for those with breast abscesses. Maternal antibiotic treatment is rarely a contraindication to breastfeeding since many antibiotics are harmless to the newborn or excreted in minimal amounts in breast milk. However, breastfeeding should be put on hold if the mother is taking metronidazole or chloramphenicol. [51,55] The safety of newer fluoroquinolones has not been evaluated. Sulfonamides should be used with caution if the newborn is premature or ill. [51]

Prevention of Transmission to and from Personnel

Prevention of Infection in Personnel

An immunization history should be obtained before employment. Personnel should be immune to rubella, measles, mumps, varicella, and HBV; should have received a dose of acellular pertussis vaccine; and should receive influenza vaccine annually. [5,168,169] Polio vaccine should be given to nonimmune personnel with risk of contact with patients excreting poliovirus. [30] Diphtheria and tetanus vaccines also should be offered. [169] Tuberculin reactivity should be determined on employment. [5,168]

Susceptible employees should not care for patients with varicella, zoster, measles, or rubella. Personnel who touch the mucous membranes of their eyes or nose during the care of patients with respiratory viral infections may become infected and subsequently transmit infection to other patients. Personnel should be made aware of the risk of such practices, which are often unconscious. [5]

Standard Precautions should be taken to minimize the risk of potential infection with bloodborne viruses. These include: hand hygiene; using gloves, gowns, masks, and eye protection to prevent exposure of the skin and mucous membranes to blood, body fluids, excretions, and secretions; using resuscitation bags, mouthpieces, and mechanical suctioning devices to eliminate the need for emergency mouth-to-mouth or oral suctioning procedures; handling patient care equipment and linen carefully to avoid contamination of skin and mucous membranes; and using precautions to reduce the risk of injury from needles and other sharp instruments. Ongoing efforts must continue to identify and evaluate sharps-safety devices in an attempt to reduce sharps exposure in the workplace. [17] Personnel should be familiar with hospital protocols for postexposure prophylaxis after occupational exposures to blood and body fluids. [5,17]

Prevention of Transmission from Personnel to Patients

Employees should be informed about the risks of transmission of communicable infections to newborns and instructed to report acute infections. It is rarely feasible to remove all persons with communicable infections from the nursery. Decisions should be made on an individual basis, taking into consideration the mode of transmission of the particular infection and the ability of the employee to comply with preventive measures. Employees with exudative or herpetic hand lesions should not have direct patient contact or handle patient care equipment. Personnel with herpes labialis are unlikely to transmit infection but should avoid touching the lesions during patient care and should cover any external lesions. Wearing a mask can prevent touching of oral lesions. [5,51] Personnel with airborne infections should not work. Nonimmune personnel with significant exposure to varicella, measles, rubella, or mumps should not work during the latter part of the incubation period because these infections can be transmitted before onset of symptoms. [17,80]

Prevention of Transmission from Visitors

Each nursery should develop and enforce a clearly defined visiting policy that allows family members to visit while minimizing risk to the infants. The advantages of allowing siblings to visit newborns has been stressed. [55] Limited data suggest that neonatal colonization and infection are not increased with such visits, if appropriate screening procedures are followed. Visitors can introduce communicable diseases such as varicella, pertussis, or RSV into a nursery, with potentially serious results. Policies should be developed for sibling visitation in the NICU and SCN. Promotion of family-centered care must be

balanced with consideration of the well-being of the infants in the nursery. This can be accomplished with guidelines to limit risk of infection exposure. [5]

Visitors should be screened for symptoms of communicable infection and for recent exposures, and individually assessed for their potential to transmit infection and their ability to comply with instructions. Persons with airborne infections such as varicella or measles or with fever or symptoms of acute respiratory, gastrointestinal, or skin infection should not visit; nonimmune persons with recent exposure to varicella, zoster, measles, or rubella also should not visit as they may be in the infectious stage of the incubation period. Visiting children should be prepared for the visit in advance. Visitors should be instructed in proper hand hygiene technique and should wash their hands before contact with the newborn. Parents should ensure adult supervision of child visitors and assist children in hand hygiene. Visitors should not have contact with other newborns in the nursery and should not handle patient care equipment. [51,55]

Visitation should take place in the mother's room or in a special visiting room whenever possible. Limiting the number of visitors at any one time and limiting the duration of visits is advisable. It may be prudent to restrict visitation during community epidemics of respiratory tract infection.

Prevention of Transmission from the Inanimate Environment

Cleaning and Disinfecting

The nursery should be kept clean and dust free. Floors, work surfaces, and other horizontal surfaces should be cleaned daily with an Environmental Protection Agency-registered hospital disinfectant, using manufacturer's instructions. [97] Walls, curtains, and window blinds should be cleaned sufficiently often to prevent accumulation of dust. Cleaning methods used should minimize dust dispersal. [5]

In addition to cleaning and disinfection between patients, equipment assigned to a single patient with a prolonged stay should be changed and cleaned periodically. [5,17] Frequency will depend on the type of equipment and the potential for contamination and dust accumulation. Equipment should be cleaned and disinfected according to cleaning and disinfection guidelines (see **Chapter 31 Cleaning, Disinfection, and Sterilization**). Items in contact with a neonate's nonintact skin or mucous membranes (e.g., resuscitation bags, masks) should be replaced and undergo sterilization or high-level disinfection on a regular basis. Incubators, warmers, and bassinets should be changed and cleaned periodically. A protocol should be in place for regular cleaning and disinfection of ventilators and replacement of ventilator circuits. The maximum duration of safe equipment use for the same patient has not been established and may vary by type of circuit. The assignment for cleaning delicate equipment, including monitoring equipment and radiant heaters, needs to be well-defined. The regular cleaning personnel should not handle these items.

Quaternary ammonium, chlorine, and phenolic compounds are acceptable low-level disinfectants for nursery cleaning. [5] These agents do not sterilize but reduce the concentration of microbes to an acceptable level. Phenolic compounds should be used with caution and should not be used on incubators or other surfaces in direct contact with the newborn, because inappropriate use has been associated with neonatal hyperbilirubinemia. [5]

Linen for newborns does not need to be autoclaved. The recommended temperatures and detergents used in the laundry process should reduce microbial contamination to insignificant levels. Clean linen should be wrapped or covered during transport from the laundry and stored in closed cabinets to prevent dust contamination. Used linen should be handled as little as possible to avoid hand contamination and aerosolization of microorganisms. [5,17]

Elimination of Sources of Waterborne Pathogens

Evaporative humidifiers in incubators are potential sources of waterborne microorganisms and should not be used in nurseries if central humidification provides sufficient humidity. The water reservoir should be drained when used, cleaned, and refilled with sterile water every 24 hours. Nebulizers and attached tubing and water traps should be replaced regularly with equipment that is sterile or that has undergone high-level disinfection. Sterile water should be used in nebulizers and humidifiers. Condensate in ventilator tubing should be drained and discarded periodically. Toys that may retain moisture, such as stuffed toys, should not be placed in incubators. [5]

Enhancement of Neonatal Defenses

Active Immunization

Failure to vaccinate newborns who will have prolonged hospitalization places them at risk if in-hospital exposure occurs. Newborns in hospital should receive diphtheria, tetanus, acellular pertussis, inactivated polio, *H. influenzae* type b conjugate, and pneumococcal conjugate vaccines at 2 months of age. Medically stable preterm infants should be vaccinated with full doses at the recommended chronological ages. [168] Response of VLBW infants to HBV vaccine given at birth is suboptimal. Newborns born to mothers who are HBsAg positive should receive HBV vaccine at birth regardless of gestational age. If birth weight is less than 2,000 grams, the birth dose of Hepatitis B vaccine should not be counted toward completion of the Hepatitis B vaccine series, and the vaccine series should be started when the infant is 1 month old. HBV vaccination of newborns of birth weight less than 2,000 grams born to HBsAg-negative mothers should be deferred until the infant is 1 month old or until just prior to discharge. All infants should receive influenza vaccine at age 6 months of age. [168] Administration of live polio and rotavirus vaccines to hospitalized infants is contraindicated because of the risk of transmission of the vaccine virus to immunocompromised patients. Rotavirus vaccine can be given just prior to discharge. [135]

Postexposure Prophylaxis

Postexposure prophylaxis is recommended to prevent or modify infection after exposure to maternal or nursery pathogens. Antibiotic prophylaxis is administered to the newborn of a mother with untreated gonorrhea, syphilis, infectious TB, or pertussis and for certain high-risk newborns with intrapartum exposure to GBS. Acyclovir is indicated for selected high-risk infants exposed to HSV. Antiretroviral prophylaxis is administered to infants born to HIV-infected mothers. Newborns exposed postnatally to pertussis, invasive *H. influenzae* type b, or meningococcal infection should receive antibiotic prophylaxis. [30,138]

HBV immunoglobulin is administered for intrapartum exposure to HBV in addition to HBV vaccine. Newborns of mothers with varicella with onset 5 days before to 2 days after delivery should receive VZIG. VZIG also is recommended after healthcare-associated varicella exposure for all hospitalized premature newborns born to nonimmune mothers and for all newborns born at less than 28 weeks' gestation. Immunoglobulin is recommended for newborns exposed to measles. [30] Immunoglobulin has been used to control nursery outbreaks of HAV and has had variable results in nursery outbreaks of enteroviral infection. [30]

Immunotherapeutic Agents

Intravenous administration of gamma globulin has not had reliable efficacy in preventing infections in premature newborns. Immunoglobulin with high antibody titer to RSV and monoclonal anti-RSV antibody (palivizumab) are protective against RSV disease and are recommended for selected high-risk infants. [30,124,125,126,129]

Neutrophil transfusions are not a practical prophylactic intervention. Data on the efficacy of granulocyte colony stimulating factor and granulocyte-monocyte colony stimulating factor in prevention of neonatal infection are inconclusive. [56]

Bacterial Interference

Artificial colonization of newborns with an avirulent microorganism to prevent colonization with a more virulent strain was used during the *S. aureus* pandemic in the 1950s to control outbreaks in nurseries. [68] Artificial colonization of the pharynx with α-hemolytic *Streptococcus* protected infants in the NICU from pharyngeal colonization with Gram-negative microorganisms. Antibiotic-sensitive *E. coli* strains were used successfully to suppress gastrointestinal colonization with resistant enteric microorganisms, and infants artificially colonized with an avirulent *E. coli* strain had fewer HAIs than control infants. [69,90,94]

Monitoring Occurrence of Healthcare-associated Infections

Surveillance for neonatal HAIs is a monitor of quality of care and permits early detection of infection trends and clusters. Setting up a surveillance program involves selection of the types of infections to be monitored, the methods of case finding to be used, and the denominator data to be collected.

CDC definitions of neonatal HAIs are based on those for older children and adults with modifications for children younger than 12 months of age. [16] Methods of case finding include prospective clinical case review, review of laboratory results, or retrospective chart review. Laboratory-based surveillance is very sensitive for bloodstream, urinary tract, and CNS infections, but is less sensitive for infections at other sites and is influenced by the availability of laboratory facilities and intensity of testing.

Surveillance in the NICU may include all infections or may be limited to specific infection sites or microorganisms. [16,64] The NHSN surveillance program monitors infections related to devices and procedures. [16,21] If resources are limited, targeted surveillance with collection of appropriate denominators related to birth weight and device use will be more useful than total surveillance without relevant denominators. When a system of ongoing surveillance has not been established or is not feasible, cross-sectional prevalence studies can help determine local priorities.

In the newborn nursery, surveillance should concentrate on infections associated with outbreaks, such as staphylococcal or streptococcal skin infections, gastroenteritis, and respiratory viral infections. Since many of these infections manifest only after discharge, close communication with community healthcare providers is essential to prevent delay in recognition of facility-based outbreaks. Active post-discharge surveillance can be performed, but is not indicated in the absence of an outbreak.

The appropriate denominators should be used to calculate infection rates. [16,21] For the newborn nursery, numbers of live births, admissions, or discharges may be appropriate if devices are not involved. For the NICU, where infection risk is related to length of stay, infection per 1,000 patient-days is a more relevant denominator. Since birth weight is a marker for severity of illness in NICUs, NHSN stratifies infection rates by birth weight (≤750 g, 751 to 1,000 g, 1,001 to 1,500 g, 1,501 to 2,500 g, >2,500 g). For device-associated infections, such as CLABSI, VAP, and CAUTI, days of device use should be used. Surgery-associated infection rates should be calculated by the type of surgery and the infection risk score. [16,21]

Conclusions

Neonates are at high risk of acquiring a wide variety of infections in the hospital environment. Technological advances have permitted more premature and ill newborns to survive, but these advances bring with them additional infection risks. Risk can be reduced by appropriate infection prevention measures.

Future Trends

- Measures to prevent premature delivery and consequent problems will have an important role in reducing the impact of neonatal infections.[5,19,22]
- Studies of the immune defenses of the neonate may lead to new ways to support the immature immune system.[1,55,56]
- Newer means of supporting lung function in the premature infant may reduce the need for long-term ventilation and the risk of pulmonary infection.[150,151]
- Novel technology, which may result in safer invasive devices (e.g., intravascular catheters, which are less prone to bacterial colonization), is being explored, and studies need to be extended to neonates. [1,2,3,62,84]
- Trials are needed for neonates with antiseptic impregnated CVCs currently in use in the adult population. Clinical trials with neonates are needed in all birth-weight categories; trials are especially needed in LBW infants.[60]
- Antibiotic locks that provide an antibiotic solution to remain in the catheter lumen have shown promise. Although antibiotic resistance has not shown to be a problem in neonates, it is still a concern and routine use has not been recommended as an option for prevention of BSIs.[60]
- The potential for feeding neonates with additive probiotics (live microbial supplements) to prevent colonization with more dangerous microorganisms warrants further exploration. Attempts to control fecal colonization with Gram-negative aerobes by feeding premature infants *Lactobacillus*were unsuccessful. Feeding older infants *Lactobacillus*was effective in reducing the risk of healthcare-

associated diarrhea.[90,134,136] Oral supplementation of breast milk with *Lactobacillus* reduced the incidence and severity of *Candida* enteric colonization in VLBW preterm infants. Further studies are warranted.[117,170]

- Immunization of the mother during pregnancy to protect the newborn against specific pathogens by providing enhanced passive immunity is under evaluation.[1,56,138]

International Perspective

The impact of healthcare-associated neonatal infection on neonatal morbidity and mortality varies with birthing practices, including the proportion of infants delivered in the hospital or at home, and the level of supportive neonatal care available.[1,5,19,55] In less-developed countries, Gram-negative bacteremia is more common, as are outbreaks of infection with enteric pathogenic bacteria.[2,3,69,84,90] Although the principles of infection prevention remain the same, it is recognized that resources for surveillance and prevention are limited and that strategies need to be prioritized, selecting those that are most feasible and most likely to have the largest impact.[3,28,55,56,84]

Supplemental Resources

The American Academy of Pediatrics: Committee on Infectious Diseases; Committee on Fetus and Newborn. Available at: **http://www.aap.org**.

The Canadian Paediatric Society: Infectious Diseases and Immunization Committee; Fetus and Newborn Committee. Available at: **http://www.cps.ca**.

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Pediatrics

Author(s): Kelly L. West, MS, RN, CIC
Infection Preventionist

Epidemiology
Children's Hospital Colorado
Aurora, CO

Ann-Christine Nyquist, MD, MSPH
Medical Director, Infection Prevention and Control

Children's Hospital Colorado
Professor of Pediatrics, Section of Infectious Diseases and Epidemiology
University of Colorado School of Medicine
Aurora, CO

Tina Bair, BSN, RN, CIC
Manager, Infection Prevention and Control

Akron Children's Hospital
Akron, OH

Wendy Berg, BSN, RN, CIC
Infection Preventionist

Infection Prevention and Control
Children's Hospitals and Clinics of Minnesota
St. Paul, MN

Steven Spencer, MD FAAP
COL, MC, USA

Chief, Pediatric Ward 3W
Walter Reed National Military Medical Center
Bethesda, MD

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Abstract

The purpose of this chapter is to help the reader understand why children are more susceptible than adults to infections, along with the factors, both intrinsic and extrinsic, that may increase this risk even further. The challenges and differences within pediatric infectious disease surveillance are discussed. Vaccine-preventable diseases, respiratory infections, and gastrointestinal infections that have a significant impact on healthcare-associated infection rates are reviewed. The chapter emphasizes strategies for the prevention and control of spread of infectious diseases including differences seen in pediatric and adult populations. Finally, the impact of broad-spectrum antibiotic use and the increasing problem of antibiotic resistance in the pediatric population are reviewed.

Key Concepts

- Unique host factors place children at risk for acquiring infectious diseases.
- Transmission to and from contacts is more likely to occur in the young child than with older children and adults.
- Although risk factors posed by the healthcare environment and care interventions are often similar to those seen in the adult population, there are many patient care interventions and approaches that are specific to the care of the pediatric patient, and the infection preventionist must be familiar with those interventions in order to recognize prevention opportunities.

Background

There are many factors unique to children that place them at high risk for acquiring infectious diseases. Young children are generally incapable of caring for themselves and rely on others for adequate hygiene. Children also come into contact with objects and equipment that may be unique, such as toys and cribs. Depending on their developmental stage, children often use their mouths to explore and discover the world around them, thereby increasing the risk for transmission of infectious pathogens. Careful consideration must be given as to how these items should be cleaned and disinfected. Physiologically, young children have relatively naive immune systems and are susceptible to infections that may not be routinely seen in, or be of little consequence in, the adult population. Congenital immunodeficiencies and anomalies pose additional risks for infection, as do certain diseases (e.g., cystic fibrosis), some of which are more common in children than in adults. These children are often hospitalized, putting them at higher risk of healthcare-associated infections (HAIs), particularly those who are admitted to a pediatric intensive care unit (PICU) and those who undergo surgeries and procedures with invasive devices. Important differences exist between children and adults with respect to the epidemiology and nature of HAIs. In addition, the interpretation and comparison of HAI rates is challenging because of the relative lack of pediatric data in existing national surveillance reports.

Some vaccine-preventable illnesses, such as varicella and pertussis, are highly transmissible and may cause significant morbidity and mortality in affected children. Infants and small children are often asymptomatic during the communicable phase of many illnesses, especially viral respiratory infections, thereby increasing challenges to the prevention of transmission. Screening for symptoms and

surveillance for these illnesses are important to prevent their spread. In addition, care should be taken to isolate these patients with prompt application of Transmission-based Precautions.

Unnecessary use of broad-spectrum antibiotics is a concern in pediatric patients. Unfortunately, rates of multidrug-resistant organisms (MDROs) are increasing in this population, as seen with methicillin-resistant *Staphylococcus aureus*(MRSA), vancomycin-resistant *Enterococcus*(VRE), andbeta-lactam-resistant Gram-negative bacilli. Therapeutic choices for these MDRO infections are becoming increasingly limited. Therefore, controlling the transmission of resistant organisms, where possible, is essential. In addition, the increasing prevalence of *Clostridium difficile*in children requires understanding the role this organism plays in colonization as well as disease.

As therapies for congenital and acquired diseases become more complex, so will the breadth of infections and care for affected patients. The following chapter highlights those aspects of infection prevention that are most relevant to the pediatric population. It focuses on hospital-based pediatrics and will, for the most part, exclude the neonatal population, which is covered in **41. Neonates**. For terms and definitions refer to **41. Neonates**.

Considerations in Pediatric Infection Prevention and Control

INTRINSIC RISK FACTORS FOR ACQUISITION OF INFECTION

Developmental Stages

Children pass through an "oral" stage of development when they explore objects by using their mouths. This stage begins and usually persists until 3 years of age (or later in developmentally delayed children).[1,2]Oral contact with contaminated objects and surfaces provides a potential entry point for infectious pathogens. Additionally, children often lack the mental and/or physical ability to assist with hygienic practices such as respiratory etiquette and are therefore reliant on their caregivers for this. Because caregivers have close contact with the secretions and body fluids of young children, education of caregivers regarding the importance of good hand hygiene, environmental sanitation, and appropriate food handling is essential to reduce their acquisition of infections from the child.

The Immature Immune System

The immune system can be broadly divided into four functional components: the B-lymphocytes, the T-lymphocytes, the phagocytes, and the complement system (Table 42-1). Neonates are relatively immunodeficient (see **41. Neonates**), but even infants and older children can be susceptible to infections because of the relative immaturity of their immune system or because they have not been exposed to a particular pathogen.[3,4]

Infants and toddlers younger than 2 years of age have decreased response to polysaccharide antigens, putting them at risk of invasive disease due to*Streptococcus pneumoniae, Haemophilus influenzae*, and *Neisseria meningitidis*. Fortunately, new conjugate vaccines (which conjugate a protein to the polysaccharide antigen) are more immunogenic and result in immunologic memory with subsequent increase in antibody with reexposure to the antigen.[5,6]

Table 42-1 Functional Components of the Immune System[3,4,5]

Component	Function

B-lymphocytes (humoral immunity)	Recognize antigens, differentiate into plasma cells that secrete antibodies (immunoglobulins), which inactivate microorganisms alone or in combination with complement or phagocytes.
T-lymphocytes (cellular immunity)	Help or suppress cell function. May also be cytotoxic, killing target cells that express foreign antigens.
Phagocytes (includes neutrophils, eosinophils, basophils, monocytes, and macrophages)	Help fight bacteria and fungi. Migrate toward site of infection (chemotaxis), ingest and kill microorganisms.
Complement system	A series of proteins divided into two pathways. The classical pathway enhances specific humoral immunity. The alternative pathway provides nonspecific immunity.

Maternal immunoglobulin G (IgG) antibody is passively acquired transplacentally. As maternal antibody wanes, children become susceptible to infections to which they have never been exposed to or adequately vaccinated against. Varicella infection, as well as pertussis in infants, is an example of such an illness. In addition, some pathogens, like respiratory syncytial virus (RSV), provoke such a limited immune response that infants become susceptible again a short time after initial infection. Influenza virus poses another challenge as infants younger than 6 months cannot receive influenza vaccine and the influenza virus changes its antigenic properties so rapidly that immunity acquired one year may be of limited value the next.[3] Because of their susceptibility to communicable diseases, it is important for all children to be vaccinated according to annually updated national guidelines.[6,7]

Immunodeficiencies

Some children have congenital (Table 42-2) or acquired (Table 42-3) immunodeficiencies placing them at high risk for infections throughout their life span. Such children vary in their susceptibility to HAIs depending on the severity and duration of immunosuppression. As with other children, routine practices and Transmission-based Precautions should be followed by caregivers and families at all times.[8,9]

Table 42-2 Infections Associated with Congenital Immunodeficiencies[10,11]

Defect	Age at the Onset of Infection	Pathogens/Infections Involved	Systems Involved
Predominant T cell (e.g., X-linked SCID, hyper-IgM syndrome)	Early, usually 2 to 6 months of age	Bacteria:mycobacteria Viruses:CMV, EBV, varicella, enterovirus Fungi and parasites: *Candida*; opportunistic infection, PCP	Failure to thrive, protracted diarrhea, extensive mucocutaneous candidiasis

Predominant B cell (e.g., X-linked agammaglobulinemia)	Onset after maternal antibodies diminish at around 6 months of age	Bacteria:*Streptococcus pneumoniae, Staphylococcus aureus, Haemophilus influenzae, Campylobacter* Viruses:enterovirus Fungi and parasites:*Giardia, Cryptosporidium*	Recurrent sinopulmonary infections, chronic gastrointestinal symptoms, malabsorption, arthritis
Phagocytic (e.g., X-linked CGD)	Early onset	Bacteria:*Staphylococcus aureus, Pseudomonas, Serratia, Klebsiella* Fungi and parasites:*Candida, Nocardia, Aspergillus*	Dermatitis, impetigo, cellulitis, suppurative adenitis, periodontitis, abscesses, osteomyelitis
Complement	Onset at any age	Bacteria:*Neisseria* spp., *Escherichia coli, Streptococcus pneumonia*	Meningitis, arthritis, septicemia, recurrent sinopulmonary infections
BCG, Bacille Calmette-Guérin; CGD, chronic granulomatous disease; CMV, cytomegalovirus; EBV, Epstein-Barr virus; IgM, immunoglobulin M; PCP, *Pneumocystis carinii*(renamed *Pneumocystis jiroveci*) pneumonia; SCID, severe combined immunodeficiency.			

Table 42-3 Infections Associated With Acquired Immunodeficiencies

Alteration	Defect	Pathogens/Infections Involved	Prevention and Control
Hematopoietic stem cell (bone marrow) transplant[12]	Pre-engraftment(0 to 30 days) • Neutropenia	Bacteria:*Staphylococcus aureus, Staphylococcus epidermidis, Viridans streptococci, Pseudomonas aeruginosa, Enterobacteriaceae, Escherichia coli, Klebsiella pneumoniae, Enterobacter* spp. Viruses:HSV Fungi:*Candida*spp., *Aspergillus*spp.	• Pretransplant assessment • Antimicrobial prophylaxis • Colony-stimulating factors • Passive immunization • Active immunization
	Early engraftment(31 to 100 days) • Cytotoxic and phagocytic functions • Impaired barriers (e.g., mucositis, catheters)	Bacteria:*S. aureus, S. epidermidis, Viridans streptococci, P. aeruginosa,* Enterobacteriaceae Viruses:CMV, respiratory viruses, adenovirus Fungi:PCP, *Candida*spp., *Aspergillus* spp.	

	Late engraftment(>100 days)	Bacteria:*Haemophilus influenzae, Streptococcus pneumoniae* Viruses:VZV Fungi:*Candida*spp.	
Solid organ transplant[13,14,15]	Early period (0 to 1 months) (depends on organ transplanted) (Listed in decreasing order of relative importance)	Bacteria:Gram-positive organisms (all) *Pseudomonas/Burkholderia*spp. (lung transplant for CF) Enterobacteriaceae (liver, small bowel, neonatal heart) Fungi:*Candida*spp. Viruses:HSV, healthcare-associated respiratory infections (all)	• Pretransplant assessment • Perioperative antimicrobials (varies by site) • Passive immunoprophylaxis • Active immunization
	Middle period(1 to 6 months)	Viruses: CMV (all, increased risk R-/D+), EBV (highest in small bowel), VZV (all) Opportunistic infections: PCP (all), *Toxoplasma gondii*(heart) Bacteria:*Pseudomonas/Burkholderia* spp. pneumonia (lung) Enterobacteriaceae (small bowel)	
	Late period(> 6 months)	Viruses(all): EBV, VZV, community-associated viral infections Bacteria:*Pseudomonas/Burkholderia* spp. pneumonia (lung) Enterobacteriaceae (small bowel) Fungi:*Aspergillus*spp. (lung with chronic rejection)	
HIV[16]	Suppression of CD4 cells and cellular immunity, humoral immune dysfunction, impaired phagocytic function	Opportunistic infections:PCP, Nontuberculous mycobacteria, CMV, Cryptosporidium Other infections:Otitis media, URTI, sinusitis, bacterial pneumonia, bacteremia, VZV, UTI, meningitis, TB	• Immunization • Prevention and treatment of opportunistic infections

Oncologic conditions[12]	Chemotherapy-induced neutropenia primary predisposing factor. Reduced lymphocyte subsets also play a role. Impaired barriers important in pathogenesis including mucositis, enteritis/colitis, invasive devices.	Bacteria:Gram-positive organisms predominate as causes of BSI; coagulase-negative staphylococci, *S. aureus,*alpha-hemolytic streptococci, *Enterococcus*spp., Gram-negative organisms, *Clostridium septicum*and *Clostridium difficile*also important organisms in this population. Viruses:HSV, VZV most commonly. Respiratory tract viruses a significant cause of morbidity as are adenovirus, measles, enteroviruses, and HHV. Fungi:*Candida*spp. Most commonly followed by *Aspergillus*spp.	• Active immunization • Passive immunoprophylaxis • Antimicrobial and antiviral prophylaxis in some situations
Asplenia (including patients with sickle cell disease)[17,18]	Predisposed to infections with encapsulated bacteria	*S. pneumoniae* *H. influenzae* *Neisseria meningitidis* *Salmonella*spp. (especially osteomyelitis)	• Penicillin prophylaxis against *S. pneumoniae* • Immunize against *S. pneumoniae, H. influenzae, N. meningitidis*
BSI, bloodstream infection; CF, cystic fibrosis; CMV, cytomegalovirus; D, donor; EBV, Epstein-Barr virus; HHV, human herpes viruses; HSV, herpes simplex virus; PCP, *Pneumocystis carinii*(now *P. jiroveci*) pneumonia; R, recipient; TB, tuberculosis; URTI, upper respiratory tract infection; UTI, urinary tract infection; VZV, varicella-zoster virus.			

The Centers for Disease Control and Prevention (CDC) recommends that allogeneic hematopoietic stem cell transplant recipients be cared for in a protective environment to minimize fungal spore counts in the air and reduce the risk of invasive environmental fungal infections.[8]Some healthcare facilities implement environmental controls and total protective isolation for all severely immunocompromised patients, but there is currently no evidence to support this. A study by Slota et al. reported that there was a reduced rate of HAIs following solid organ transplantation when staff practiced strict hand washing, but this decreased rate did not statistically differ from the group that was randomized to gown and glove use.[19]

Critical evaluation of total protective isolation is imperative to ensure the effective and appropriate utilization of limited healthcare resources.

Viral shedding, especially when detected with polymerase chain reaction, in respiratory secretions, urine, or stool can be prolonged in immunocompromised patients, persisting even after clinical symptoms have resolved. Community respiratory virus infection in immunocompromised hosts has been documented to last up to 4 months for influenza, 112 days for RSV, and 140 days for norovirus. Therefore, to prevent healthcare-associated transmission, units that care for immunocompromised patients should factor the potential for prolonged viral shedding into policy decisions about duration of precautions for infected patients.

Special mention should be made of the environment as a reservoir for particular infections in immunocompromised patients. For instance, *Legionella*spp. and filamentous fungi such as *Aspergillus*spp. may be problems in institutions undergoing construction/renovation.[20] These organisms can cause serious, potentially lethal disease in immunocompromised children.[21] National guidelines and resources for infection control protective precautions to be taken during construction and renovation are available elsewhere.[8] Information regarding construction and renovation can be found elsewhere in this text.

Inherited or Congenital Disorders

Like adults, children may be born with or acquire disorders that place them at higher risk of infection. Often, these children are hospitalized at a young age and often require invasive procedures and monitoring, which puts them at risk of acquiring HAIs. Examples of such diseases are outlined in Table 42-4.

Table 42-4 Examples of Inherited/Congenital Disorders and Related Infections

Defect	Risks	Intervention(s)
Upper gastrointestinal and airway defects		
Cleft palate[22]	-Recurrent otitis -Aspiration pneumonia	
Tracheoesophageal fistula and/or atresia[23]	-Introduction of oral secretions or food into trachea results in aspiration pneumonitis and/or pneumonia	-Prevent or reduce episodes of aspiration -Decrease secretions -Parenteral alimentation -Surgical repair
Lower gastrointestinal tract defects		
Hirschsprung's disease Meckel's diverticulum Intussusception Perforation	-Enterocolitis -Perforation/peritonitis -Gangrenous bowel	-Discontinue feeds -NG decompression -Intravenous fluid and electrolyte therapy -Parenteral alimentation -Systemic antimicrobials as indicated for infection -Surgical intervention

Short gut syndrome[24,25,26,27]	-Sepsis—risk factors: translocation from GI tract, central venous catheters	-NG feeds -Parenteral alimentation -Systemic antimicrobials as indicated for infection
Inflammatory bowel disease[28,29,30]	-Fistula and abscess potential complications of Crohn's disease -Patient is often on immunosuppressive medications, which can increase viral infections -Sepsis more likely if short gut present	-Patients may be on chronic suppressive antibiotic therapy -Systemic antimicrobials as indicated for infection
Biliary atresia[31]	-Recurrent episodes of bacterial cholangitis in 50 percent after Kasai procedure -Require liver transplant with subsequent complications	-Better studies needed to evaluate efficacy of chronic suppressive antibiotics -Systemic antimicrobials as indicated for infection
Defects in closure of skin and/or subcutaneous tissues[32,33]		
Omphalocele Gastroschisis Bladder exstrophy	-Risk of exposing underlying tissues and organs to microbial contamination and invasion -Device related infection as applicable	-Protect underlying tissues -Cover defect with sterile gauze -Prevent drying of tissues -Position infant to reduce pressure on defect -Provide controlled environment to decrease exposure to microorganisms -Do not remove wrap for unnecessary examination *Parenteral alimentation -Repair surgically; may require several stage procedures
Cutaneous defects[34,35]		
Aplasia cutis Epidermolysis bullosa Ichthyosis	-Local infection -Secondary sepsis	-Meticulous hygiene
Genitourinary system abnormalities		

Vesicoureteral reflux Hypospadias Neurogenic bladder Obstructive lesions that alter kidney function (e.g., hydronephrosis)	-Recurrent urinary tract infections	-Antimicrobial therapy for infections -Consider antimicrobial prophylaxis -Surgical intervention for correction of anomaly
Nephrotic syndrome[36]	-*Streptococcus pneumoniae*infections due to urinary loss of immunoglobulins -Complications of immunosuppressive therapy (e.g., severe varicella in those treated with steroids) -Complications of dialysis	-Antimicrobial prophylaxis -Active immunization -Passive immunoprophylaxis following varicella exposure if patient is treated with high dose steroids
Central Nervous System		
Neural tube defects	-Myelomeningocele presents similar problems as with defects in closure of skin and/or subcutaneous tissues in addition to meningitis and complications related to VPS	-Meticulous hygiene -For VPS infection prevention, see neurosurgical procedures
Respiratory Tract		
Cystic fibrosis[37,38,39]	-Pulmonary colonization/infection with -*Staphylococcus aureu*s (including MRSA), *Pseudomonas* spp., *Burkholderia cepacia,*nontuberculosis *Mycobacterium*	-Strict adherence to infection prevention and control practices -Adequate disinfection of respiratory therapy equipment -Physical separation of patients infected or colonized with MRSA, B. cepacia -Antibiotic prophylaxis -Physiotherapy -Adequate caloric intake -Education of patient, family about personal hygiene, respiratory etiquette, and hand hygiene

GI, gastrointestinal; MRSA, methicillin-resistant *Staphylococcus aureus*; NG, nasogastric; VPS, ventriculoperitoneal shunts.

EXTRINSIC RISK FACTORS FOR ACQUISITION OF INFECTION

Important external sources of infection include household, school and day care contacts, human milk, and infant formula. These risks are explained in more detail in **43. Perinatal Care**, and **41 Neonates**. Invasive devices and surgical procedures pose additional risks for acquisition of infection. In addition,

contacts including healthcare personnel (HCP), visitors, and other children are important vectors for transmission of infection. All of these are discussed in the next section.

SURGICAL INTERVENTIONS

Surgical site infections (SSIs) remain the most common HAIs following surgical procedures.[40] Due in part to national reporting requirements of SSIs, including in pediatrics, there is a larger focus on measures to decrease rates of SSIs. In a study of 61 PICUs in the United States, SSIs and bloodstream infections (BSIs) were reported more frequently in infants 2 months or younger (33.7 percent) versus older children (26.3 percent).[41] Several studies cite increased costs to patients due to SSIs. However, because National Healthcare Safety Network (NHSN) surgical risk index is based on adult surgical data, its applicability for comparing infection rates may not be valid in the pediatric surgical population.[40] SSI rates, by service, are highest for cardiovascular, neurosurgical, and orthopedic surgery.

Cardiovascular Surgery

Children undergo cardiothoracic surgical (CTS) procedures mainly to repair a variety of congenital defects. Common procedures include ventricular septal defect, atrial septal defect, coarctation of the aorta, and hypoplastic left heart syndrome repairs. SSIs, particularly superficial ones, are the most common HAIs following CTS. In one study of 726 pediatric cardiothoracic surgical procedures, SSIs occurred in 6.3 percent of the procedures of which 47.8 percent were superficial, 15.2 percent were deep tissue, and 37 percent were classified as organ space or mediastinitis.[42,43] Mediastinitis, although much less serious in pediatric patients, still occurs in 0.2 to 5 percent of all pediatric cardiovascular surgeries performed.[44,45] Due to the minimal amount of tissue along the infant or child's sternum, classifying mediastinitis per NHSN definitions can prove to be challenging. The most common pathogens causing SSI following pediatric CTS are *S. aureus*(39 percent) and *Staphylococcusepidermidis*(13 percent).[46] The complexity of congenital heart defects and the technically demanding and often lengthy corrective surgical procedures make it difficult to accurately determine risk factors for infection. However, reported risk factors for SSIs have included perfusion time in excess of 1 hour, excessive bleeding, low cardiac output state for 24 to 72 hours postoperatively, pediatric risk of mortality scores above 10 at the time of admission, delayed sternal closure, specific open-pump surgical procedures, age younger than 1 month, high American Society of Anesthesiologists (ASA) scores, longer periods of postoperative ventilatory and/or inotropic support, longer duration of surgery, undergoing more than one cardiothoracic operative procedure, and having a preoperative infection.[47,48,49] Finally, nasal colonization with *S. aureus*has been reported as a risk factor for wound infections after cardiac surgery in adult populations justifying recommendations for preoperative decolonization with mupirocin.[50] MRSA colonization may be more common in children than in adults and preoperative mupirocin may be of benefit in some high risk patients. Delayed sternal closure is a well-established management strategy following pediatric CTS with an overall reported incidence of 4 to 14.4 percent.[51,52,53] It is typical for the sternum to remain open until the patient's condition has stabilized; one group reported a mean delay of just under 4 days.[53] Typically, the sternum is covered with an occlusive dressing and patients are given varied regimens of antibiotic prophylaxis until the sternum is closed. Some studies report that delayed sternal closure is associated with longer length of stay and higher postoperative infection rates.[46,52,53] Reported rates of infection in children with delayed sternal closure range between 0 and 28 percent. Conflicting opinion exists over whether delayed sternal closure is itself a risk factor for infection or whether it is a marker for more severe underlying illness and the associated higher surgical risks for those cases. Preventative

strategies should include hand hygiene, administration of prophylactic antibiotics within 1 hour of incision, preoperative hair removal (although rarely needed in pediatric procedures), preoperative showering with chlorhexidine gluconate (CHG), use of appropriate surgical skin antisepsis, maintenance of aseptic technique intraoperatively, maintenance of hemostasis, and postoperative monitoring of dressings which include a dressing that allows for a moist, healing environment. In addition, nasal decolonization with mupirocin should be considered, particularly in high-risk patients.[54]

Extracorporeal membrane oxygenation (ECMO) is a form of life support that provides cardiopulmonary bypass in critically ill patients with reversible cardiac or pulmonary failure. ECMO requires the venoarterial cannulation of major vessels, usually for days to weeks. Risk factors for infection may include cannulation of the major vessels, alteration of host immune function, multiple portals of entry in the ECMO circuit, prolonged cannulation, the use of broad-spectrum antibiotics, complexity of the underlying cardiac defect, and adjunctive management strategies including delayed sternal closure.[55,56]

Data published on more than 51,000 patients indicate that ECMO use for pediatric respiratory failure has nearly doubled since 2000 and 13,000 pediatric patients have been treated with survival to discharge rates of 49 percent.[56] However, infections found in 26 percent of patients requiring ECMO support included bacterial (54 percent), fungal (27 percent), mixed (14 percent), and viral (5 percent) organisms. Types of infections include primarily BSIs, SSIs, pneumonia, and urinary tract infections (UTIs).[57] Fungi have emerged as important pathogens in patients on ECMO, likely related to the use of broad-spectrum antibiotics and resulting yeast colonization.[55,56,58] A cluster of BSIs due to *Ralstonia pickettii* associated with contaminated ECMO temperature-control units underscores the importance of proper equipment handling and maintenance.[59]

Neurosurgery

Common neurosurgical procedures in pediatrics include myelomeningocele repair, craniotomy, laminectomy, and cerebrospinal fluid (CSF) shunt procedures. Of these, CSF shunt procedures have the highest rates of infection.[60] CSF shunts are used to treat hydrocephalus, a common condition of childhood often associated with other diseases or conditions such as spina bifida, head injuries, intraventricular hemorrhage, meningitis, brain tumors, and other congenital anomalies.[61] In the United States, approximately 70,000 hospital admissions are associated with CSF shunt placement procedures on an annual basis.[61] The reported infection rates range from 4 to 20 percent.[61,62,63,64,65] CSF shunt infections usually occur within the first few months after the surgical procedure and are associated with an increased risk of seizure disorder, decreased intellectual performance, and a long-term risk of mortality that is greater than 30 percent—almost double that observed in children without infection.[63] Risk factors for CSF shunt infections vary depending on the etiology of the hydrocephalus,[64] prematurity,[61,66] postoperative CSF leaks,[60] glove breaches,[60] presence of a previous CSF shunt system,[66] previous CSF shunt infections,[66] CSF shunt insertions involving the use of neuroendoscopes,[67] and the duration of the CSF shunt surgery.[62] CSF shunt infections are usually caused by typical skin organisms such as *S. aureus*, coagulase-negative *Staphylococcus* spp., and *Propionibacterium* spp. but have also been associated with *Enterococcus faecalis* and different Gram-negative rods.[64,67,68]

Preventive strategies include preoperative hair shampoos and abdominal washes with an antibacterial agent, preferably one with a residual effect such as CHG. Length of hospitalization prior to surgery

should be minimized. Meticulous surgical technique, with a particular focus on preventing CSF leaks, is essential.[60,68,69] Limiting traffic in the operating room and not shaving the scalp have also been shown to minimize infection.[68,69] Antimicrobial prophylaxis should be administered perioperatively.[68,69,70,71,72,73] Postoperatively, the wound should be kept clean and dry,[68] which may be challenging with diapered patients. When sampling the CSF, strict adherence to sterile technique is extremely important to avoid contamination.

Intrathecal baclofen therapy is becoming more common in the management of spasticity and dystonia in children.[74,75] As with other implantable devices, perioperative antibiotic prophylaxis is required.[70] In one single center study, only a 5 percent infection rate was seen and 50 percent of the isolates growing *S. aureus*. However, 59 percent of patients with documented infection required explantation of the device. Risk factors have not been identified for these infections, although at one center, a change in technique and a different antibiotic prophylaxis regimen improved SSI rates.[74,75] Pediatric patients tend to have more overall surgical and wound complications when undergoing this procedure than do adults.[76,77,78,79]

Orthopedic Surgery

A practical approach to classifying orthopedic procedures considers whether or not there is an implant and whether or not the procedure is for musculoskeletal injury. Some children may undergo diagnostic or therapeutic operations for musculoskeletal infections such as diskitis, septic arthritis, or osteomyelitis. The ability to benchmark pediatric orthopedic procedure against NHSN data is limited because they are not differentiated from adult cases.[80]

Spinal fusion procedures, as a result of severe scoliosis, are the pediatric orthopedic surgical procedure of major concern to infection prevention personnel. Scoliosis may be idiopathic, or it may arise secondary to neuromuscular disorders such as cerebral palsy, muscular dystrophy, or myelomeningocele. Surgical correction for scoliosis involves spinal fusion with or without insertion of rods for stabilization. SSIs following posterior fusion and instrumentation are more frequent after surgery for neuromuscular scoliosis than after surgery for idiopathic scoliosis.[80,81,82] Identified risk factors have included obesity, antibiotic prophylaxis with clindamycin, inappropriately low dose of antibiotics, a longer duration of hypothermia during surgery, and ASA score of greater than two.[83,84] Polymicrobial infections involving Gram-negative and anaerobic organisms have been reported in patients with neuromuscular disorders, and expanded antibiotic prophylaxis regimens have been recommended.[85] This recommendation has not, however, been subjected to rigorous study. The wound vacuum-assisted device may have a role in treatment of early deep infections, but further study is required.[86]

Fractures in children are more common in males and in adolescents, often associated with sports injuries such as soccer, basketball, or inline skating. The distal forearm is most frequently involved. Open fractures are particularly prone to infection, and early parenteral antibiotics are often indicated. In a study examining the effect of delayed surgical treatment on rate of infection in open fractures in children, Skaggs et al.[87] found that operative irrigation and surgical debridement could be delayed more than 6 hours if early parenteral antibiotics were given (infection rate 2.5 percent with definitive treatment within 6 hours, 1.6 percent if more than 6 hours).[88,87,89]

Head and Neck Surgery

The reasons for performing craniofacial surgeries in children are different than those for adults. The most common reason is craniofacial deformity, including craniosynostosis repair. The SSI rate is approximately 3 percent after intracranial surgery for craniofacial malformations including synostosis. This rate increases substantially when the paranasal sinuses are transgressed.[90]

Special mention should be made of the association between cochlear implants and meningitis. Children with cochlear implants should have their immunizations kept up-to-date, especially those vaccines for encapsulated bacteria such as *S. pneumoniae, H. influenzae*type B, and *N. meningitidis*.[91,92]

BURNS

Although the outcome of children with burns has improved with the advancement of burn management, including aggressive surgical treatment and use of topical antimicrobial agents, the risk of morbidity and mortality remains high.[93,94,95,96]Eighty percent of burns in children are the result of scald injuries, followed by flame, electrical, and chemical injuries.[97]Burn victims are at risk for HAIs such as burn wound infections, BSIs, pulmonary infections, and UTIs. Pediatric patients are at greater risk of burn wound infections than adult patients.[98]

Challenges exist in benchmarking pediatric burn infection rates, since the NHSN system reports only adult burn intensive care units (ICU) data. Some pediatric burn centers have reported infection rates using modified definitions and total body surface area percentage to stratify infection rates.[98,99]As with adults, most infections in pediatric burn patients are caused by *S. aureus*, including MRSA. Gram-negative bacilli such as *Pseudomonas aeruginosa*and *Enterobacteriaceae*and fungi, including *Candida*spp., have been linked to late-onset infections.[93,98,100]

The most common risk factors for infection include age, depth and location of the burn, preexisting diseases, and use of invasive devices. Burn wounds that involve more than 30 percent of the total body surface area have an increased risk of becoming infected, as they are more heavily colonized. This is also true of the site of the burn as sites below the waist have more often been reported as the most common sites of infection.[99]Preexisting diseases, including immunodeficiency and diabetes, have been demonstrated to increase the risk for fungal infections in burn patients.[99]Principles of prevention include adherence to good hand hygiene practices, meticulous wound care (especially in diapered children), environmental cleaning, and judicious use of antibiotics to prevent emergence and transmission of resistant pathogens in this vulnerable population. Further, evaluation of surveillance data from targeted infection sites may help to improve management of patient care and, ultimately, outcome.[98]Information regarding the unique aspects of infection prevention in patients with burn injury can be found in **38. Burns**.

INFECTIONS ASSOCIATED WITH INVASIVE DEVICES

Hospitalized children are at risk for similar device related infections as adults: central line-associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTI), and ventilator-associated events. Prevention strategies differ from adult populations in a few important ways.

Bloodstream Infections

Strategies for the prevention of CLABSIs in acute care hospitals have been published, including recommendations and addressing controversies in pediatric care.[101] Bundles of evidence-based practices have proven useful in reducing the incidence of BSIs in children as in adults.[102,103,104,105,106] There are, however, unique considerations in pediatrics.

A child's developmental stage may pose additional challenges in securing and caring for central lines. For example, care must be taken to secure central lines away from the diaper area to prevent stool contamination. Mobility and activity level of the child may necessitate additional securement to protect it from dislodgement if tension is put on the line in the course of play or activity. While additional securement is often necessary, it is essential to maintain clear visibility of the insertion site to allow frequent site assessment for infiltration, extravasation, skin breakdown, or localized infection. Opaque dressings or self-adherent wraps may seem to offer good securement but put the patient at risk of delayed detection of complications with the line and should not be used.

Pediatric specific modifications to the maximal sterile barrier for central line maintenance or insertion include asking parents to mask if they remain in the room during the procedure and loosely draping a young child or infant's head with a blanket if they are unable or uncooperative with wearing a mask.

In some pediatric and neonatal patients, the risk of dislodgement of the central line may outweigh the benefit of weekly dressing change. Thus, a clinician may choose to defer the central line dressing change to avoid losing the line.[103] Unlike the adult population, use of the femoral vein for a central venous access is not associated with increased complications or infection among pediatric patients.[102, 103]

Many pediatric facilities have become accustomed to the use of CHG, either impregnated in a dressing, as a skin antiseptic for central line placement, and/or as a daily bath, with generally positive results. One large, multicenter, randomized crossover study found that daily CHG baths resulted in decreased bacteremia among PICU patients, and were well tolerated by patients.[105] Until recently, product labeling on CHG skin antiseptics have stated that use in infants younger than 2 months is contraindicated. This language has been modified based on changing U.S. Food and Drug Administration (FDA) approval to "use with care" in the younger than 2 month age group, reflecting both current practice in pediatric and neonatal settings and evidence on product safety; however, additional study is needed.[102, 103] Levy et al. found that using a CHG-impregnated dressing at the central venous catheter (CVC) exit site significantly reduced the risk of CVC colonization in children in a cardiac ICU. However, no difference in the rate of CLABSIs was noted.[107]

Evolving care models have resulted in increased use of CVCs in the outpatient, ambulatory, or home care settings. Rinke et al. found that pediatric oncology patients are three times as likely to have a CLABSI in the ambulatory setting than while inpatient.[106] Increasing attention and study of the use of care bundles for central lines in the ambulatory and home setting in addition to comprehensive line care education of caregivers is necessary to address this changing landscape in healthcare.

Dannenberg et al. reported that the ethanol-lock technique plus antibiotics resulted in fewer infectious relapses than antibiotics alone in the treatment of BSIs in pediatric oncology patients with catheters.[108] Antibiotic locks may be useful in specific situations.[109] A Cochrane database review by Schoot et al. on the utility of antibiotic or ethanol locks in children with cancer, in addition to systemic antibiotics, found

no clear benefit; however, there were limited existing randomized controlled trials and further study is warranted.[110] A prospective randomized study is necessary, however, to adequately determine its benefit.

Use of evidence-based bundle practices, both for insertion and maintenance of CVCs, have shown a reduction in rates of CLABSIs in pediatric centers; however, it is unclear whether all practices in the bundle or a specific piece in the bundle play a larger role.

Principles used for insertion bundle include: Performing hand hygiene prior to procedure; use of CHG to scrub insertion site for 30 seconds in all areas except for the groin, which should be scrubbed for 2 minutes; eliminate use of iodine skin prep or any ointment at the insertion site; develop insertion kits that contain all supplies needed; create an insertion checklist; maintain aseptic technique when inserting central lines; use only polyurethane or Teflon catheters; and train all staff on proper insertion techniques.[107,111]

Maintenance bundle practices have included daily assessment of need for line access, catheter site care, no use of iodine/ointment, use CHG scrub to sites for dressing changes, gauze dressings are to be changed every 2 days unless soiled or loose, clear dressings are changed every 7 days unless soiled or loose, use prepackaged dressing change kit, abide by appropriate catheter hub, cap and tubing care, replace administration sets no more frequently than every 72 hours, replace tubing that is used to administer blood/blood products or lipids every 24 hours from start of infusion, perform cap changes no more often than every 72 hours, and consider a prepackaged cap change kit or supply area to standardize practice.[102,103,106]

Respiratory Tract Infections

Diagnosis of ventilator-associated pneumonia (VAP) is challenging in all patient populations because of the poor sensitivity and specificity of clinical, laboratory, and radiographic changes compared to histopathology. VAP diagnosis is even more problematic in neonatal and pediatric patients. The difficulties in diagnosis can be similarly applied to surveillance; that is, despite standardized definitions, variations can arise leading some authors to conclude that interhospital comparisons of VAP rates may be unreliable.[112,113,114,115] To address these concerns, NHSN developed revised definitions for adult populations in 2012.[112,115] The revised surveillance definitions broaden the focus from VAP, defining a more general category, called ventilatory-associated events (VAE). Subclassifications of ventilator-associated conditions and infection-related ventilator-associated complications offered further specificity in classifying these events.[112] These definitions specifically exclude individuals younger than 18 years old; however, to address the need to define and measure VAE in the pediatric population, in 2012 the CDC convened a Neonatal and Pediatric VAE Working Group to explore the feasibility of developing VAE surveillance definitions and methodology in PICU and neonatal ICU (NICU) populations.

Despite the challenges in defining and measuring ventilator-associated complications, there is growing consensus that the consistent application of bundles of evidence-based practices is an effective strategy to reduce the incidence of VACs in the pediatric population, although most of the recommendations are extrapolated from adult studies. Strategies to prevent VAP have been published.[116,117]

Urinary Tract Infections

CAUTIs are less common in the pediatric population than in the adult population. Most microorganisms causing CAUTIs come from the patient's own colonic and perineal flora (a particular risk in pediatric patients who are incontinent of stool) or from the hands of HCP during catheter insertion or

manipulation of the collection system.[118] The most common uropathogens seen include *Escherichia coli*, *Enterococcus*, *P. mirabilis*, and *Klebsiella*.[119,120] In small children, catheters may not be secured by a cuff thus enabling the catheter to migrate in and out of the urethra and bladder, which can theoretically increase infection risk. Diagnosis of CAUTI tends to be difficult in young children and those who are critically ill and unable to report symptoms. Fever is often the presenting symptom. Strategies to prevent CAUTI in pediatric patients are nearly identical to those in adults.[121,122] The creation and use of CAUTI bundles for pediatrics have been increasing in the last several years and include the following: use aseptic technique for insertion, avoid unnecessary catheterization, maintain a closed drainage system, secure the catheter, maintain hygiene, keep urine collection bag below the level of the bladder, maintain an unobstructed flow, and promptly remove catheter when no longer required.

A review of the literature also showed that implementing urinary catheter reminders and stop orders also appear to reduce rates of CAUTI in hospitalized patients. Although specifics have been left up to individual pediatric centers to determine, additional work needs to be done to understand the impact of these bundle elements and their role in the reduction of pediatric CAUTI.[123]

ENVIRONMENT

Children frequently harbor and can shed infectious organisms even when asymptomatic. Whether children are ill or not they often want to explore their environment and play. In addition, children often may be in close proximity to one another and spend time in common areas, such as playrooms or waiting areas where sharing of contaminated toys and equipment is likely to occur. Multiple studies document the extended length that organisms can remain on environmental surfaces which enhances the potential for transmission of organisms through contact between hands and the surface and confirms the need for regular rigorous environmental cleaning.[124]

Inpatient Healthcare Environments

Most pediatric facilities have playrooms or activity rooms. These areas should be for patient use only. Guidelines should be written and posted as to the rules for use of these rooms outside of the patient's own room. The infection prevention department should have a policy on playroom use, keeping in mind things like admitting diagnosis, fever, or other symptoms of illness should be considered when writing policies for playrooms/activity rooms. A pediatric patient should not be allowed into the playroom while they are in any type of isolation. Only toys that can be properly cleaned and disinfected should be allowed into isolation rooms. Playroom visitation can be allowed once patient is out of isolation precautions.

Outpatient Healthcare Facilities

Minimal published literature documents infection acquisition in the ambulatory care setting, although there have been reports of transmission of tuberculosis (TB) and measles in pediatricians' offices.[125] It cannot always be assumed that pediatric patients are at lower risk in the outpatient setting as an increasing number of medically complicated children are being treated at home. These children may have compromised immune systems, be on ventilators, or have central lines to deliver medication. The environmental surfaces in a pediatrician's office (e.g., exam table, waiting room furniture) should be disinfected after each patient and/or on a daily basis. Access to hand hygiene with either an alcohol-based hand rub (ABHR) or sink should be available for all clinic staff as well as patients and family members.

Residential facilities for pediatric patients and their families provide complex infection prevention and control challenges. A recently developed comprehensive document detailing recommendations for specific diseases and pathogens for preventing transmission of infectious agents in "home away from home" residential settings is helpful for infection preventionists (IPs) in their assessment and engagement with these facilities.[126]

Toys

Toys are used for therapeutic, recreational, and educational purposes. Toys and play have been shown to reduce pain, discomfort, and fear by providing a diversion for children during hospitalization. However, toys may become contaminated and colonized with contagious pathogens.[127,128,129] Studies have shown a correlation between environmental contamination and toys. One study comparing rates of coliform contamination of soft toys (90 percent) and hard toys (14 percent) in general practitioners' waiting rooms has been described.[130] An outbreak of multidrug resistant *P. aeruginosa* on an oncology ward related to bath toys has been described, as has a rotavirus outbreak in a similar population.[128,129] A decrease in HAI rates was described in a pilot study after soft toy removal in a NICU.[131]

Table 42-5 Strategies to Minimize Infection Risk with Toys[131,132]

General information	Toys should be new. Hand hygiene should be practiced by patients before and after handling toys.
Policies and procedures	Healthcare settings should have written policies regarding toy cleaning/disinfection procedures.
Cleaning and disinfection	Clean and dirty toys should be clearly separated at point of use. Responsibility for cleaning/disinfection should be assigned to particular staff, and they should be properly trained. A process for appropriate toy acquisition should be in place to ensure suitability for cleaning/disinfection; toys should be nonporous and able to withstand rigorous mechanical cleaning. Avoid toys that are water-retaining, plush, and stuffed (an exception is therapeutic dolls, which should be single-patient use) and those that are difficult to clean and dry. Toys should not be used if there is no identified process or designated personnel to manage the acquisition and cleaning of them. Toys should be cleaned and disinfected between patients, especially those that are visibly soiled, mouthed, or used by patients in isolation. Toys that are noted to come in contact with patients' mucous membranes and/or are soiled must be removed from circulation immediately and cleaned and disinfected. Toys should be washed thoroughly; disinfected with a nontoxic, low-level disinfectant (e.g., hypochlorite solution 1:100); and air-dried completely. Alternatively, a detergent disinfectant may be used as a single agent. Toys, including playhouses/climbers and playrooms surfaces, that are frequently touched by infants and toddlers should be cleaned and disinfected daily. Otherwise, they should be cleaned and disinfected at least weekly.
Monitoring compliance	An audit process should be in place to monitor adherence to the policies to further minimize potential infection risk.

CONTACTS

Visitors

Children and adults who accompany patients may transmit infection. A study by Munoz et al. evaluated adults accompanying children hospitalized for suspected TB at a children's hospital and determined the frequency of undiagnosed, potentially contagious disease in adults to be 15 percent.[133] Ideally, all visitors would be screened for evidence of communicable diseases, recent exposure to communicable diseases, and, in some instances, vaccination history.[134] Priority would be given to infections that are highly transmissible, including varicella, measles, gastrointestinal and respiratory tract infections, and any other highly communicable diseases that are circulating in the community at a given point in time. However, workload issues and the desire for family-centered care often make this difficult, and so centers should develop individualized policies, depending on the impact of contagious diseases and available resources. An exceptional circumstance exists when children are admitted with suspected or confirmed TB. In this scenario, it is particularly important to screen adult visitors and family members for active TB, as they are often the source of the infection. Visitors and parents may need to have their hospital activity restricted or be excluded completely if they are infectious. Education for parents and other visitors on the importance of hand hygiene and Transmission-based Precautions is necessary.

Healthcare Personnel

Children often require complex care administered by a multidisciplinary team. This includes HCP in addition to support staff. Staff may transmit infection to children and vice versa. For this reason, it is important for staff to maintain up-to-date vaccinations.[135,136,137] Rates of influenza vaccination among HCP may differ from place to place. Due to an increase in healthcare facilities implementing mandatory influenza vaccination policies, the rates of vaccination have increased in recent years. Vaccination rates have been reported to have increased to 72 percent up from 66.9 percent and 63.5 percent from the previous two years.[137] It is imperative for infection preventionists and occupational health and safety departments to work together to educate HCP about the importance of preventing influenza in the pediatric hospital setting by receiving an annual influenza vaccination.[137]

Staff should also be monitored regarding their TB status in accordance with published guidelines.[138] Transmission has occurred from HCP to patients in the pediatric setting.[139,140] Finally, a mechanism should be in place whereby symptomatic staff report to a supervisor and refrain from working during the communicable phase of any illness.[141]

Animal-assisted Interventions

Animal-assisted interventions (AAI) have been used in a variety of healthcare facilities for many years and are further described in **122. Animals Visiting in Healthcare Facilities**.[142] Pediatric facilities are no exception and these patients may have contact with visiting animals during AAI.[143] However, transmission of infectious pathogens from animals to humans may occur by four basic routes: contact, airborne, vectorborne, and fomite.

Dogs, cats, and gerbils may be colonized with organisms such as *Salmonella*, *Campylobacter*, *Giardia*, and *Cryptosporidium*. Reptiles are also common carriers of *Salmonella* spp. Cats can transmit *Bartonella* and *Toxoplasma*. Bites from canines and felines can become infected.[144] Emerging zoonoses

are also a concern, particularly with exotic pets (e.g., monkeypox, associated with prairie dogs).[145] High-risk species should be excluded from the healthcare facility including reptiles, nonhuman primates, hamsters, gerbils, mice, rats, hedgehogs or prairie dogs, and other animals that have not been litter trained. The risk of zoonotic disease transmission in AAI programs is very low.

Table 42-6 Guidelines for Prevention of Zoonotic Disease Transmission in Animal-assisted Intervention Programs[142,143]

AAI Policies	Animal Handling	Surveillance	Cleaning/Infection Control
Policies should be developed by HCFs for animal visitation programs.	Patients, visitors, and HCP should practice hand hygiene before and after each animal contact.	Development of a tracing mechanism is suggested in case of an event of potential zoonotic patient infections.	Routine cleaning of the environmental surfaces should occur after animal visits.
Healthy, owned adult dogs or cats (enteric pathogens are more common in puppies and kittens) that have predictable and adaptable behavior should be used.	An animal visit liaison(s) should be designated and be aware of all animals entering the premises.	Frequent veterinary examinations, up-to-date vaccinations, and consideration of mandatory deworming and ectoparasite control are necessary.	Patients with wounds, dermatitis, and/or indwelling medical devices should have these areas fully covered. If this is not possible, animal exposure should be avoided.
Animals should not be permitted entry into HCFs if they have certain medical conditions. Detailed guidelines may be found in Chapter 122 Animals Visiting Healthcare Facilities.	Unleashed animals should be contained within a pet carrier when not with the patient(s).	For purposes of outbreak management or potential zoonotic patient infections, a method should be in place to facilitate contact tracing of the AAI animals and animal handlers.	Immunocompromised patients with high risk of infection should either avoid animal contact or wear gowns and perform hand hygiene after animal contact.
They should be trained to defecate and urinate outside.	Animals must be well groomed (and bathed if soiled or malodorous) prior to visiting the HCF.	Before visitation, all animals should be screened by a veterinarian for skin infection and gastrointestinal pathogens.	Patients with indwelling medical devices (e.g., intravascular lines) should have entrance covered by clothing or gown to avoid animal exposure.
They must be supervised at all times and should be restricted from certain areas. Detailed guidelines can be found in Chapter 122 Animals Visiting Healthcare Facilities.	Animals should have fresh water sources at all times.		Surfaces where the animals rest, such as chairs/beds, should be covered and then changed after use.
Animals must be excluded if the animal has been fed any raw and/or unprocessed foods of animal origin within the past 90 days.			
Specific guidelines are available regarding animal exposure to hematopoietic stem cell transplant recipients.[146]			

AAI, animal-assisted intervention; HCF, healthcare facility; HCP, healthcare personnel

SURVEILLANCE

Performance of routine surveillance is important to define the endemic rates of infection, identify increases in infection rates above baseline, identify specific risks of infection for patients undergoing common hospital procedures, and inform HCP of their infection risk. Once risks are defined, preventive strategies can be devised and used.

In the era of public reporting, surveillance of HAIs is used as a measure in health facilities to measure quality of care. While many public reporting mandates favor adult metrics, several remain applicable in pediatrics. However, surveillance of HAIs and their epidemiology in pediatrics is different from adults and understanding the epidemiology of HAIs in children is an ongoing issue as most surveillance programs and subsequent data analysis are adult focused and cannot be generalized to the pediatric population.[147]

In 1999, a national multidisciplinary group met to discuss the current state of children's health services including the need for specific information about pediatric infection control issues, particularly those related to CDC identified HAIs.[148] In the 13 years that followed, a considerable amount of work has been done in the area of HAI prevention in pediatrics, particularly around CLABSI prevention in high risk areas (i.e., PICUs, oncology). In 2006, the National Association for Children's Hospital's and Related Institutions (NACHRI) launched a national collaborative for pediatric facilities to evaluate the current state of CLABSIs in their facilities and ways to reduce these rates. Initial focus in PICUs, including insertion and maintenance bundles, spread to the pediatric hematology and oncology groups beginning in 2009.[149]

Data from the NACHRI PICU study shows a continually decreasing rate of CLABSI from the participating PICUs due to continual focus on consistent adherence to pediatric specific line insertion and maintenance bundles during the study. It is unknown whether certain elements used in the bundle had effect but Miller et al. reported that the use of CHG scrub for entering central lines or CHG-impregnated sponges did not produce any statistically significant addition to reduction rates.[149] Few other surveillance benchmarks are available for pediatrics, but most centers cite the NHSN system data.[150,151,152,153]

Unfortunately, the NHSN system rates are only reported for NICU patients, making comparison of rates in non-NICU patients impossible. In the absence of these tools, it is important for centers to perform routine surveillance in a standardized manner for purposes of internal comparison. Another challenge exists with surveillance in the PICU, because the NHSN system data reflect a combination of surgical and medical patients, despite significant differences in these patient populations and their risk factors for infection.[154] Among surgical patients, cardiothoracic and general surgery patients may differ in infection rates and device utilization ratios. Currently, these patient populations are not separated when compiling and interpreting HAI rates.

In 2012, several children's hospitals joined the federally funded network, the Ohio Children's Hospitals Solutions for Patient Safety, as a result of eight Ohio pediatric hospitals' work in reducing patient harm, including prevention of device-associated infections. Research is ongoing and will be necessary to determine if accurate benchmarks may be used across the pediatric patient spectrum.

Healthcare-associated respiratory and gastrointestinal infections are usually caused by seasonal pathogens circulating in the community, especially viruses such as RSV, influenza, and rotavirus.[155]

Surveillance during peak seasons should be performed for these infections because of their significant morbidity and mortality in children and young infants.

Surveillance for MDROs should also be considered (see section on the impact of antibiotic use and resistance).

PATHOGENS

Healthcare-associated pathogens in children differ from those in adults. Viruses cause a significant number of these infections and may have a greater impact on a pediatric unit than on an adult unit. Children are known to have prolonged shedding of microorganisms and therefore may be contagious for longer than is typical for adults. Varicella, RSV, pertussis, and measles present a difficult infection prevention problem in the susceptible infant population due to the large numbers of nonimmune patients and the ease with which the infections are transmitted.[155,156]

Screening for infectious diseases in children who present to the hospital and instituting Transmission-based Precautions based on symptoms are important measures to prevent further spread of the disease. Similar challenges exist in screening patients as were outlined for screening visitors. Important pediatric pathogens are discussed in the following text.

Vaccine-Preventable Illnesses

Since the introduction of the*H. influenzae*type B vaccine in the 1990s, *S. pneumoniae*and *N.meningitidis*are the most common causes of bacterial meningitis in children.[157]Pertussis and varicella are vaccine-preventable diseases that have a significant impact on hospital infection prevention, not only because they are highly transmissible, but because patients can be most infectious before they are symptomatic. Rotavirus is another vaccine-preventable disease in children that has been associated with transmission in the healthcare setting.[158,159]

Pertussis

Unvaccinated adults, including HCP, are the main sources of healthcare-associated pertussis.[160]

Conversely, HCP may be infected with pertussis following exposure to infected patients. The Advisory Committee on Immunization Practices (ACIP) recommends that adolescents and adults who anticipate close contact with an infant younger than 12 months old should receive a single dose of tetanus-diphtheria-acellular pertussis (Tdap), if they have not previously received it.[161,162]Vaccination of patients, parents, and staff should be ensured as cocooning is an effective way to protect young infants from pertussis. Making Tdap available to patients' families is a cocooning strategy that would help decrease pertussis among children too young to be vaccinated.[163,164]Following unprotected exposure, or in the event of an institutional outbreak, close contacts should receive prophylactic antibiotics, regardless of immunization history.[161,162]

Varicella

Most people in temperate climates are immune to varicella as they approach adulthood, but children remain susceptible unless vaccinated. The epidemiology of varicella is changing since the incorporation of the varicella vaccine into the routine immunization schedule for children. However, one dose of the vaccine is not 100 percent effective at preventing disease.[165,166,167,168]Therefore, in the United States, it is recommended that children be vaccinated at 12 to 18 months of age and again at 4 to 6 years old. A second, catch-up dose is recommended for individuals who have only received one dose.[166,169,170]

Varicella virus is highly infectious and may result in significant morbidity and mortality, particularly in

immunocompromised patients.[168,169,171,172] Severity of illness varies by age, with infants, adolescents, and adults experiencing more severe illness than children.[166,168,169,170,171] Recent outbreaks of varicella in the hospital setting are not described in the literature; however, varicella exposures from infected staff have been reported, especially in neonatal units where virtually all patients are susceptible.[172]

Measles

Measles has been virtually eliminated in developed countries, but international importation of these diseases still occurs, placing susceptible individuals, many of whom are unvaccinated children, at risk.[173,174] One example was a 2012 outbreak in Hennepin County, Minnesota, in which international travel by an unvaccinated person resulted in 13 epidemiologically linked cases of measles; 12 of whom were children. Eight of the 13 patients were hospitalized as a result of their illness. Two of the 13 acquired measles in an emergency department waiting room.[175] This example highlights the importance of continued vigilance with screening for vaccine-preventable illnesses and the prevention of spread of disease by prompt isolation of even suspected cases, prophylaxis of contacts, and adherence to national vaccination guidelines. A challenging scenario exists with immunocompromised children in whom live virus vaccines may be contraindicated or in whom the immune response to vaccinations may be attenuated. These children and their contacts require heightened screening and surveillance for vaccine-preventable illnesses.

Rotavirus

Prior to the introduction of a vaccine for rotavirus, it was the most common cause of healthcare-associated diarrhea in young children.[176] The virus is present in stools of infected people for several days before and several days after symptoms. Fomites are thought to play a role in transmission, making attention to toys and other hard surfaces handled by young children important to interrupting transmission.[177] Contact Precautions are indicated.

Viral Respiratory Infections

Healthcare-associated viral respiratory infections have been well documented among pediatric patients.[178] The most common respiratory viruses causing upper or lower respiratory infections among pediatric patients are adenovirus, influenza, parainfluenza, RSV, rhinovirus, human metapneumovirus (hMPV), and coronavirus. Several studies have noted that coinfection with more than one respiratory virus is not uncommon in patients with bronchiolitis.[179] Due to this, identification of one etiologic agent does not rule out other viruses as coinfectors. Despite differing modes of transmission among the various respiratory viruses, Contact and Droplet Precautions are indicated as not all viruses may be identified in symptomatic patients. In addition, infants and children are often held or within close contact with their healthcare providers.

Respiratory Syncytial Virus

RSV and human hMPV are two of the leading causes of respiratory infections requiring intensive care for pediatric patients.[180,181] Children with underlying conditions such as prematurity, cardiac or pulmonary disease, or immunosuppression are at highest risk of mortality from RSV.[182,183,184] Prophylaxis with palivizumab is recommended for high-risk patients.[185,186]

RSV is transmitted by direct or close contact with contaminated secretions[187,188] including inhalation of large respiratory droplets and contact with contaminated fomites. The environment may play an important role in transmission because the virus can remain viable for several hours on fomites and at least 30 minutes on hands.[188] Hand hygiene, disinfection of surfaces, and Contact Precautions are key elements of infection prevention. If single patient rooms are limited, cohorting patients with RSV has also been suggested as an effective prevention strategy.[179,189] Isolation should be indicated based on clinical symptoms rather than laboratory testing and last for the duration of symptoms. During outbreaks, visitors may need to be restricted to help control RSV transmission. A robust process for screening families and visitors for respiratory illness, with masking or exclusion of symptomatic individuals during the peak winter viral illness months, may support prevention efforts for hospital-associated respiratory infections.

Influenza

Young children from birth to 4 years of age are second only to the elderly in hospitalizations for influenza.[190] Certain underlying conditions, such as chronic metabolic disease and neuromuscular disorders, are associated with more severe disease among pediatric patients.[191]

Influenza virus has been linked to transmission in pediatric units[192] and transmission has been successfully interrupted with prompt implementation of Droplet Precautions. Patients may be infectious in the 24 hours before symptoms develop, and peak infectiousness is typically within the first three days of illness.[193,194] The importance of infection prevention measures in pediatric outpatient clinics and emergency departments, where patients initially seek care for influenza illness, is critical. Prolonged viral shedding among immunocompromised patients and young children may require prolonged use of isolation precautions in these populations.[194,195] Annual vaccination is recommended for all children aged 6 months and older.[196,197,198] Even when there is a partial mismatch between the vaccine and the circulating strains, vaccination against influenza can still provide protection against flu-related complications.

Other Viruses

Healthcare-associated transmission of parainfluenza has been reported in oncology units.[199] hMPV is being increasingly recognized as a respiratory pathogen in children. Like RSV, it causes upper and lower respiratory tract disease and appears to be seasonal in distribution. Institutional outbreaks due to hMPV have been described in adults. Transmission is likely to occur through direct or close contact with contaminated secretions, and patients should be cared for under Contact Precautions.[200,201,202]

Tuberculosis

Acquisition of TB in children is typically through inhalation of infectious particles expelled by another person, usually an adult with active pulmonary disease from the same household. There are also rare reports of transplacental transmission and, most recently, transmission from a newborn with congenital TB to another baby in a NICU, which may have resulted from contact with contaminated equipment.[203]

Most children infected with *Mycobacterium tuberculosis* are asymptomatic, have latent infection, and are therefore not contagious. Older children and adolescents are more likely to experience reactivation disease and may present with constitutional symptoms. Children from areas where TB is endemic can

present with involvement of almost any organ system. Young infants and immunocompromised children are more likely to have disseminated disease. A tuberculin skin test or an interferon-gamma release assay and chest radiograph are useful diagnostic tools, but the definitive diagnosis of TB disease is difficult in young children who are unable to expectorate. Gastric aspirates and bronchoalveolar lavage specimens are often sent for mycobacterial culture instead of sputum in these children. Children with pulmonary symptoms suggestive of TB should be isolated in a negative-pressure room with Airborne Precautions until the disease can be ruled out or until they are no longer contagious. Family and visitors to children with suspected TB should be evaluated for active TB, as other adult household members are the most likely source of infection for children with TB. Visits by children should be discouraged because of their increased susceptibility.[204,205]

Gastrointestinal Infections

Most hospitalizations due to gastroenteritis are secondary to dehydration among infants and young children. Healthcare-associated transmission and outbreaks have been described due, in part, to the ability of several gastrointestinal viruses to live on surfaces and hands for prolonged periods of time.[206,207,208,209,210,211] In general, prevention and control of viral gastroenteritis transmission should include single-room or cohort isolation with Contact Precautions. ABHRs are recommended as an adjunct to hand washing to prevent patient-to-patient transmission of gastrointestinal infections. Norovirus outbreaks have been reported in long-term care facilities and psychiatric settings and require extensive infection prevention involvement to mitigate and contain.[212,213] Immunocompromised hosts tend to be more susceptible than their immunocompetent counterparts. *C. difficile* is a recognized cause of infection and outbreaks in the pediatric healthcare setting, and appear to be increasing in incidence.[214] The emergence of the hypervirulent BI/NAP1 strain of *C. difficile* has heightened interest and concern over this infection.[215] Some pediatric centers have reported an increasing incidence of both healthcare- and community-associated *C. difficile* infections. Asymptomatic colonization with toxigenic *C. difficile* is frequent in children younger than 1 year of age and testing of stools in this age group is discouraged except for unique situations.[214] Transmission risk from children younger than 1 year of age is unclear.

THE IMPACT OF ANTIBIOTIC USE AND RESISTANCE

The selective pressures of antibiotic therapy have promoted the emergence of MDROs worldwide. For children in the community setting, this is most evident for infections caused by *S. pneumoniae*, whose increasing resistance to penicillin has necessitated the use of more complicated and expensive empiric and therapeutic antibiotic regimens. MDROs involved in HAIs generally differ from those acquired in the community, with MRSA, VRE, and beta lactam-resistant Enterobacteriaceae being the major nosocomial MDROs of concern. A recent report of healthcare-associated BSIs in children noted that antibiotic resistance steadily increased over a 6-year period.[216] The problem of MDROs is urgent for a number of reasons: implications for antibiotic treatment, indirect and direct costs of therapy, and HAIs because of their poor immune defenses, exposure to antibiotics, and invasive procedures.[217,218] Children in the PICU with HAIs due to antibiotic-resistant organisms have been shown to have increased length of stay and increased mortality.[219,220]

Nasal carriage of MRSA in healthy children is widespread and the incidence of MRSA infection continues to increase both in the community and in the hospital. MRSA colonization is a risk factor for subsequent MRSA infection in children.[221] Predominant infections include skin and soft tissue infections, osteomyelitis,

pneumonia, and bacteremia. MRSA colonization rates within PICUs and NICUs range from 1 to 2 percent to more than 5 percent.[221,222,223,224,225,226] Effective control of healthcare-associated transmission of MRSA requires a comprehensive, multifaceted, and prolonged approach.[224] MRSA is resistant to all beta-lactam antibiotics, and increasingly to other antibiotics. Vancomycin continues to be the drug of choice for invasive MRSA infections in the pediatric population. Newer classes of antibiotics approved for use in adults are useful adjuncts with refractory or difficult to treat infections.

Vancomycin resistance in *Enterococcus faecium*and *E. faecalis* is of concern because of the limited therapeutic options available for serious disease and because of the potential for the resistance gene to transfer to other organisms such as *S. aureus*.[227] Colonization rates of VRE in highly antibiotic exposed populations such as pediatric hematology/oncology and hepatology/gastroenterology patients can range from 10 to 30 percent of patients. Previous antibiotic therapy with third-generation cephalosporins has emerged as a major risk factor for acquisition of VRE. Hospitalized children colonized with VRE can be silent reservoirs for subsequent transmission.[225,226,227,228,229]

Beta lactam-resistant Gram-negative bacilli are of particular concern in patients in ICUs and in immunocompromised patients where third-generation cephalosporins are commonly used. Although beta lactam resistance in *E. coli*and *Klebsiella*species are usually caused by plasmid-mediated extended-spectrum beta lactamases, and are chromosomally determined for other coliforms (e.g., *Enterobacter, Citrobacter)*, movable genetic elements can incorporate either resistance mechanism and transfer resistance across species. These organisms usually remain susceptible to carbapenems and to fluoroquinolones; paradoxically, carbapenems induce the very enzymes (beta lactamases) that hydrolyze other beta lactam antibiotics, keeping carbapenems intact. Overall, the incidence of antimicrobial resistant Gram-negative organisms causing infections in critically ill patients is increasing.[230,231]

Judicious antibiotic usage is key to reducing the emergence of antibiotic-resistant organisms and effective infection control is essential to limit transmission of resistant organisms. Balancing family-centered care with the need for stringent infection prevention measures, for example VRE, requires engagement of the infection preventionist with the care team and family to educate all about hand hygiene and other infection prevention modalities. Antibiotic stewardship programs have proven useful in pediatric populations, although the optimal strategies necessary to exert the greatest impact on antimicrobial resistance remain to be defined.**232-234**

In addition to judicious antibiotic use, surveillance (routine and enhanced), Standard and Contact Precautions, environmental measures, education, and decolonization (as appropriate) are strategies to prevention and control of MDROs. Further details are available in the 2007 Healthcare Infection Control Practices Advisory Committee guidelines on managing patients with MDROs in the healthcare setting.[9]

Conclusions

In summary, pediatric patients differ from adults in their susceptibility and response to infection. These patients often require more direct care, which places their providers at higher risk of transmitting and acquiring infections. Situations such as the use and cleaning of toys for children are unique to pediatrics and require special strategies to mitigate transmission of infections. There are subtle differences in isolation practices for children, such as the use of Droplet plus Contact Precautions for viral respiratory

infections. It is extremely important to remember these differences when caring for pediatric patients to prevent and control the spread of infectious diseases.

Future Trends

Although the focus in pediatric HAI prevention has been on CLABSIs, more study is needed to understand the epidemiology of these infections in certain pediatric populations such as the pediatric oncology population.

More data on pediatric HAI rates outside of the PICU are needed to facilitate accurate benchmarking of HAI rates instead of comparing pediatric data to adult data. In addition, better, validated scoring systems that help to assess the risk of HAIs in children are needed.

Pediatric research into prevention of device-associated HAIs is ongoing. More study is needed to understand the role certain organisms play in causing infections in certain pediatric populations (e.g., pediatric oncology). In summary, there are tremendous opportunities for infection prevention research and development in the pediatric population.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Perinatal Care

Author(s): Mary T. Post, RN, MS, CNS, CIC
Director, Infection Prevention

Oregon Patient Safety Commission
Portland, OR

Lori K. Irwin, RN, MSN, CNS
Professional Practice Leader

Women and Children's Services
Oregon Health and Sciences University
Portland, OR

Emily A. Ackiss MPH, CIC
Infection Preventionist

Department of Infection Prevention and Control
Oregon Health and Science University
Portland, OR

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Abstract

Outcomes for the woman and the newborn are interdependent and determined by multiple factors, including the woman's health and risk factors for infection, preconception care, prenatal care, intrapartum care, and postpartum care for both the woman and newborn. The well-being of the woman and the newborn requires a vigilant and collaborative approach by the woman, her family, and her healthcare providers. Policies and practices must address prenatal screening and care, intrapartum care, and postpartum management. Current evidence-based recommendations for screening to detect specific infections, treatment of infections, and antibiotic prophylaxis should be followed. Policies must include the use of Standard Precautions, health standards for personnel, aseptic techniques, dress code, visitor policies, environmental cleaning, and reprocessing of equipment. Facility design for obstetrical and newborn areas should follow current guidelines. A targeted surveillance program and analysis of

healthcare-associated infections in women and newborns should be established, with the goal of decreasing the risk for healthcare-associated infections.

Key Concepts

- Infections remain a leading cause of perinatal morbidity and mortality.
- Strict adherence to standard obstetrical infection prevention practices in delivery suites and birthing centers are crucial for the safety of both mother and baby.
- Infection prevention in obstetrics is unique because the woman's well-being and obstetrical management influence the risk for infection for the woman, the fetus, and newborn.
- The outcomes for the woman and newborn are interdependent and determined by multiple factors.

Background

Historically, perinatal infections were associated with significant morbidity and mortality for both the woman and the newborn. Group A streptococcal (GAS) infection was commonly referred to as "childbed fever" and caused significant mortality in women. In 1847, Dr. Ignaz Semmelweiss recommended the use of hygienic measures, such as physician hand washing, before assisting a delivery. This resulted in decreased infections and the resulting morbidity and mortality.[1] Dr. Semmelweiss met serious resistance from his medical colleagues and was ultimately dismissed from the Vienna hospital where he worked. His theory that good hand washing before assisting a delivery would prevent puerperal fever was not accepted until after his death.

The challenge for current obstetrical infection prevention is to minimize the risk for healthcare-associated infections (HAIs) while supporting family-centered maternity care. Partnering with the family (father, partner, or support person [doula]) is an important part of the birthing experience. There is no published evidence, to date, that the presence of support persons during delivery increases infection rates if instruction is given on delivery room protocol and if those attending are free of communicable diseases. Children, when present, must be screened for acute infection and adequately supervised. A safe environment should be provided for both the family and healthcare providers in the setting in which the birth occurs (whether in a hospital, a birthing center, or at home), through the use of evidence-based infection prevention practices and through innovative environmental design. Throughout the pregnancy and the postpartum period, communication between the obstetrical and nursery teams should be frequent to ensure that host factors of the mother and interventions implemented do not adversely affect the well-being of the fetus and neonate. Improvements in antenatal care, treatment and prophylaxis of infections, and improved aseptic techniques and operative standards have all contributed to a significant decrease in infections and mortality in both the mother and newborn.

The ongoing development of new technologies and interventions to assist the high-risk obstetrical patient requires that infection preventionists (IPs) continually review and verify that policies and procedures are being followed. Furthermore, the introduction of rapid and reliable laboratory methods for the detection of organisms such as group B streptococcus (GBS) and herpes simplex virus (HSV) should improve the management of the patient in the delivery suite.[2,3,4] To meet the goals outlined earlier, this chapter is organized to follow the woman through preconceptual, prenatal, intrapartum, and

postpartum care. In the same manner, the implications for the fetus and newborn are addressed. Organisms are addressed in the discussion of prenatal care.

Basic Principles

An infection prevention and control program that supports a positive and infection-free perinatal experience for both the mother and the newborn includes assessing for the following: the risk for infection, hand hygiene, Standard Precautions, aseptic technique, operative technique, appropriate facility design, instrument and equipment reprocessing, appropriate treatment or prophylaxis, and occupational health for
employees.

DEFINITIONS

The following terms are of importance in the discussion of infection in the setting of pregnancy and delivery.

- **Amniocentesis:**Surgical transabdominal or transcervical penetration of the uterus for aspiration of amniotic fluid
- **Birthing center:**A facility, either free-standing or associated with a hospital, where all stages of maternal and newborn care are provided and the family and/or support persons may remain with the woman as much as possible throughout the birthing process[5]
- **Cesarean section (C-section):**Operative procedure to deliver the newborn
- **Chorioamnionitis:**Inflammation of the fetal (amniotic) membranes
- **Congenital infection:**Illness existing at birth; may be a result of influences arising during gestation up to the moment of birth; may or may not be clinically apparent at birth
- **Delivery:**Expulsion or extraction of the newborn, placenta, and fetal membranes
- **In utero:**A Latin term literally meaning "in the womb"
- **Intrapartum infection:**Infection occurring as a result of exposure to organisms at the time of labor and delivery
- **Endometritis:**Infection of the interior epithelial lining (endometrium) of the uterus
- **Episiotomy:**Surgical incision in the perineum and vagina for obstetrical purposes
- **Infection of the newborn (neonatal):**Infection occurring in the first 28 days of life
- **Labor/delivery/recovery room (LDR):**Room used for labor, delivery, and recovery care; postpartum care occurs elsewhere
- **Labor/delivery/recovery/postpartum room (LDRP):**Room used for all stages of maternal and newborn care[6]
- **Obstetrical HAI:**Infection that is neither present nor incubating when the patient is admitted to the hospital
- **Perinatal infection:**Infection acquired during pregnancy or delivery
- **Postpartum (postnatal) infection:**Infection acquired following birth
- **Prenatal:**Period from conception to onset of labor
- **Puerperal infection:**Infection of the genital tract, usually the uterus, following delivery

- **ROM:**Rupture of (fetal) membranes or amniotic fluid sac
- **Standard Precautions:**A group of infection prevention practices that apply to all patients, regardless of diagnosis or presumed infection status (see **29. Isolation Precautions (Transmission-based Precautions)**)
- **Stillbirth:**Fetal death occurring at ≥ 20 weeks' gestation (early preterm, < 28 weeks; late preterm, 28 to 36 weeks; term: > 36 weeks)

Interventions to Improve Health Outcomes for the Woman and Her Newborn

Factors that affect the health outcomes of the woman and newborn are as follows:

- Prenatal care with screening and appropriate interventions for the prevention, early diagnosis, and prompt treatment of infections and health-related conditions or behaviors that affect pregnancy and outcome.
- Consistent use of Standard Precautions with all blood and body fluids, such as amniotic fluid, placenta, and vaginal secretions, as well as in handling the newborn before the first bath.
- Effective and consistent hand hygiene (soap and water or alcohol-based hand rub) compliance should be monitored.
- Appropriate interventions during labor and delivery, whether in the hospital or for home delivery to decrease the risk of intrapartum transmission of infection (e.g., antibiotic prophylaxis as indicated, aseptic technique in the operating room, safe medication practices, proper insertion and management of intravenous catheters, urinary catheter, and regular perineal care).
- Use of evidence-based surgical procedures and guidelines.
- Use of well-designed labor and delivery rooms and operative delivery rooms.
- Postpartum care for the woman and her newborn.
- Selective antibiotic and immunoprophylaxis for the newborn.
- Prevention of postnatal transmission of infection from mother to newborn.
- A healthy workplace policy for all healthcare providers.

Environmental Design

The traditional labor and delivery room is no longer the only place for a woman to deliver her newborn. Women may choose to give birth in a birthing center or at home. Hospitals are providing a variety of accommodations for women in the form of LDRPs, the more traditional LDRs, and operative delivery rooms. Regardless of the type of healthcare accommodation used, healthcare facilities must design patient rooms, operative delivery rooms, sinks, and their heating, ventilation, and air-conditioning systems to prevent transmission of infection to the woman and her newborn.

When designing new obstetrical spaces or renovating old spaces, the design team should include representatives from the perinatal team, an architectural firm, planners, engineers, functional programmers, facility services, and infection preventionists.[5]The design should incorporate the recommendations outlined in the Facility Guidelines Institute (FGI) *Guidelines for Design and*

Construction of Health Care Facilities, *Guidelines for Perinatal Care,*[6] and the Centers for Disease Control and Prevention's (CDC) guidelines for environmental infection control.[7] Because of new and emerging infectious diseases in all populations, design and renovation of obstetrical spaces should consider the need for airborne isolation rooms and positive-pressure operative delivery rooms with a negative-pressure anteroom and a negative-pressure recovery room.[7] There should be accurate airflow monitoring of these rooms.[7] The operative area must meet all the standards for surgical suites, including proper ventilation and solid ceilings.[8] Assuring easy and convenient access to hand hygiene stations while designing the unit is essential. Planners should also consider designing space for the co-bedding of multiples.

Ideally, the unit should be designed to allow the rapid assessment of the patient for communicable disease and patient triage into an appropriate room based on the assessment. Single rooms are preferred. Each room must have hand-washing facilities, private toilet facilities, and, ideally, a shower or bathtub.[5] Well-designed, durable, and impervious materials must be chosen for all surfaces and equipment so they can be easily cleaned. The unit design must provide areas for the safe management of soiled patient care equipment, linens, and instruments.

Some institutions allow the use of tubs and whirlpools for hydrotherapy for the laboring woman as well as water birth. It is important to note that if these are incorrectly designed or not cleaned adequately, infections from *Pseudomonas aeruginosa, Legionella*, and other waterborne organisms can occur.[7] If used for the birthing process, this equipment must be designed so there is no backflow in the lines and jets. The lines are to be flushed, cleaned, and disinfected thoroughly between patients. Birthing tanks and other tub equipment must be drained after each patient use and surfaces thoroughly cleaned and disinfected. An inflatable tub is an alternative solution, but it must be cleaned and disinfected between patients, if not single-use. The use of a tub liner does not eliminate the need for cleaning and disinfection. If the bath is designed, cleaned, and disinfected according to standards, studies indicate that there appears to be no increase in infection in the woman or newborn. [7]

Cleaning and Disinfection

Basic principles of cleaning and disinfection of surfaces are to be followed. For specific information, see **107. Environmental Services**.

There must be no sharing of equipment or instruments between patients without appropriate cleaning, disinfection, and/or sterilization. For example, sitz baths are best used as disposable, single-patient devices. If reusable sitz baths are used for multiple patients, there must be a protocol in place for their management to ensure that the baths are appropriately cleaned and disinfected between patients. If shared between multiple patients, blood glucose meters should be cleaned and disinfected after every use. Insulin pens and other medication cartridges and syringes are for single-patient use only and should not be shared between patients.[9] Items such as thermometers, electrocardiogram leads, stethoscopes, and fetal monitoring belts must be cleaned and disinfected between patients according to cleaning and disinfection guidelines (see **31. Cleaning, Disinfection, and Sterilization**).

Ultrasound probes may be used on intact skin or transvaginally. It is necessary to verify that ultrasound equipment is receiving the appropriate level of cleaning and disinfection. Probes used transvaginally

must be covered with a condom and receive a minimum of high-level disinfection between patients; the use of a condom or sheath does not negate the need for high-level disinfection.[10]

Invasive diagnostic interventions and procedures such as amniocentesis, chorionic villus sampling, transvaginal ultrasound, and cervical cerclage are potential causes of intra-amniotic infection. The use of appropriate aseptic techniques during the procedure and reprocessing the equipment according to current standards is necessary.[10] Incubators, open-bed warmers, and bassinets must be thoroughly cleaned between newborns following manufacturers' recommendations.[6] Because exposure to disinfectants may be harmful to the newborn, the bassinet or incubator should not be cleaned with a disinfectant when the newborn is in it and the product chosen should leave no harmful chemical residues (e.g., phenolics).

Interdisciplinary Communication

Healthcare team members should establish methods for communication concerning conditions, plans, and outcomes regarding the care of the mother and newborn. Communication improves preconception planning, antepartum, intrapartum, and post-delivery intervention for the woman and her newborn (e.g., screening results that require immediate or long range treatment such as positive results for sexually transmitted infections [STIs], human immunodeficiency virus [HIV], GBS, diabetes, tuberculosis, hepatitis, or altered immune status). Joint morbidity and mortality rounds between the neonatal and obstetrical teams provide a useful forum for review and standardization of practice.

Preconception Care

Preconception consultation with a healthcare professional is encouraged for identification of any conditions that could affect the pregnancy or health status of the woman or fetus where interventions could be implemented to improve outcomes. The goal is optimal health before conception.

Strategies for prevention include the following:

- Review of the woman's immunity and immunization status: vaccination should be offered to women who are or who are planning on being pregnant and who are found to be at risk for or susceptible to rubella and varicella; also, if live virus vaccines are given to women of childbearing age, appropriate contraception should be used for the post-vaccination period in accordance with the recommendations of the Advisory Committee on Immunization Practices (ACIP).[11]
- Screen for Hepatitis B surface antigen.
- Screen for HIV, which is strongly recommended. If the result is positive, also screen for Hepatitis B virus (HBV) and Hepatitis C virus (HCV) because coinfection increases risk for complication.[6]
- Assess nutrition and diabetic status.
- Screen for STIs, including syphilis, chlamydia, and gonorrhea. Women at high risk for STIs should be counseled regarding the impact of high risk behaviors on a potential pregnancy and fetus.
- Offer Mantoux tuberculin skin test with purified protein derivative or interferon-gamma release assay (if indicated) for women at risk of tuberculosis. A positive or intermediate test result should warrant evaluation with chest x-ray and review of her history to determine further evaluation.[6]

Prenatal Care

Health information obtained at the first prenatal visit provides a baseline risk assessment from which continued care can be planned and accomplished. Entry into care should occur early in pregnancy so testing and treatment can be implemented and complications for the woman and newborn avoided.[6]

Nutrition and weight status should be assessed as they are related to overall health status. Conditions such as malnutrition, diabetes, and heart disease can increase a woman's vulnerability to infection (e.g., HBV). An oral health assessment should be performed because a potential benefit of improving oral health is that it may decrease transmission of cavity-causing bacteria from mother to baby. In addition, oral health problems are associated with other diseases (e.g., heart disease, diabetes, and respiratory infections). Untreated periodontal disease may lead to bacteremia.[12]

Prenatal screening should include a baseline urine screen for protein and urine cultures to detect asymptomatic bacteriuria. Verification of rubella and varicella-zoster immunity should be obtained. Screening for syphilis, *Chlamydia trachomatis, Neisseria gonorrhea*, Hepatitis B surface antigen (HBsAg), HIV, tuberculosis, and GBS should also be part of the process. For women who continue to be at high risk of acquiring an STI during their pregnancy, testing should be repeated in the second and/or third trimesters and, for some infections, repeated again at delivery (e.g., syphilis). Consideration should also be given to testing for HBsAg for women who are seeking testing for or are diagnosed with an STI during pregnancy. It is recommended that serology screening for syphilis be conducted for all women at the first prenatal visit, repeated for women at high risk or previously untested early in the third trimester and postpartum, and for women who deliver a stillborn infant.[6]All infants born to seropositive mothers must undergo careful examination and an initial Venereal Disease Research Laboratory (VDRL) test or rapid plasma reagin and confirmatory testing (treponemal). Skin lesions or moist nasal secretions of congenital syphilis are highly infectious.[13]When an STI is detected, CDC guidelines for treatment and investigation of the newborn should be followed (see **91. Sexually Transmitted Diseases**).[14]Testing for HIV is strongly recommended for all pregnant women and should be offered as part of routine prenatal testing with an option for refusal (opt out), following local and state regulations.[6,15]Women should receive education and counseling before HIV screening. Results or refusal of testing should be documented, and healthcare personnel should refer to state or provincial laws regarding consent for and disclosure of HIV status.

Immunizations

INFLUENZA

ACIP currently recommends that women who will be pregnant during the influenza season should be offered influenza vaccine regardless of trimester.[16]Pregnant women are at greater risk of influenza complications and have a higher mortality and hospitalization rates than nonpregnant women.[6,13] Canada's National Advisory Committee on Immunization[17]and the European Centre for Disease Prevention and Control[18]also provide information on the provision of seasonal influenza vaccination. Live attenuated vaccines should not be administered to pregnant women.[6]

TETANUS-DIPHTHERIA-PERTUSSIS

The CDC recommends administration of a tetanus-diptheria-pertussis (Tdap) during pregnancy, preferably during the third or late-second trimester (between 27 and 36 weeks of gestation) with each pregnancy. If not administered during pregnancy, Tdap should be administered immediately postpartum[11] and should also be offered to household members and caretakers of the newborn to ensure pertussis immunity and decrease the risk of spreading pertussis to the newborn.

OTHER

Rubella vaccine should be provided postpartum, prior to discharge if indicated (nonimmune status as determined by prenatal screening). Breastfeeding is not a contraindication to receiving the rubella vaccine. Women should avoid becoming pregnant within 1 month of the vaccination, even though the teratogenic risk to the fetus is theorectic.[6]

Pregnancy is a contraindication to administration of all live-virus vaccines, except when susceptibility and exposure are highly probable and the disease to be prevented poses a greater threat to the pregnant woman or fetus than does the vaccine.[13] For a full list, refer to

http://www.cdc.gov/vaccines/pubs/preg-guide.htm.[19]

Hepatitis A vaccine is approved, if indicated, in pregnancy. For information regarding ACIP recommendations for vaccination and breastfeeding, refer to **http://www.cdc.gov/vaccines/acip/committee/guidance/rec-vac-preg.html**.[20]

Common Organisms and Infections

The female genitourinary tract is colonized with a variety of organisms including lactobacilli, diphtheroids, β-hemolytic and nonhemolytic streptococci, enterococci, coagulase-negative staphylococci, micrococci, *Peptostreptococcus*spp., *Bacteroides*spp., *Candida*spp., *Mycoplasma hominis*, and *Ureaplasma urealyticum.* These are generally nonpathogenic or opportunistic pathogens at best. Members of the Enterobacteriaceae family (e.g., some strains of *Escherichia coli*), α-hemolytic streptococci (especially group A and group B), and *Staphylococcus aureus*are pathogenic organisms that can cause serious disease for both the woman and the newborn. The emergence of multidrug-resistant organisms (MDROs) such as methicillin-resistant *S. aureus* (MRSA), vancomycin-resistant enterococci (VRE), and extended-spectrum β-lactamase producers add another layer of concern because treatment options are limited.

The outcome of infections in pregnancy depends on a multitude of factors, including virulence of the organism, route of transmission, infectious dose, genetic factors, and host immune status. A maternal infection can be symptomatic or asymptomatic, primary or secondary, chronic or recurrent (e.g., HSV). All infections can impact on the well-being of the fetus or newborn (Table 43-1). Genital tract infections are a common identifiable risk factor for preterm premature rupture of membranes (PPROM). The full impact of infection is dependent on the maternal immune status and, in some cases, gestational stage at which the infection occurs. For example, primary rubella infection during the first to the twelfth weeks of gestation results in congenital rubella syndrome up to 85 percent of the time.[13]

Table 43-1 . Maternal Infections That Affect Outcomes for Newborns

Organism	Prenatal	Intrapartum	Postpartum

Herpes simplex virus	X	X	X
Cytomegalovirus	X	X	X
Rubella	X		X
Varicella-zoster	X		X
Enterovirus	X	X	
Listeria	X	X	X
Toxoplasma gondii	X		
Hepatitis B		X	X
Hepatitis C	X	X	
Human immunodeficiency virus	X	X	X
Parvovirus B19	X		
Untreated syphilis	X	X	
Chlamydia trachomatis	X	X	
Neisseria gonorrhoeae	X	X	
Multidrug-resistant organisms		X	X
Group B streptococcus	X	X	X

GROUP B STREPTOCOCCUS (GBS)

Serotype III of Lancefield's GBS (*S.agalactiae*) is the most common (95 percent of cases) cause of early-onset neonatal meningitis and most late-onset neonatal sepsis in the United States. Perinatal transmission of GBS commonly occurs from the woman's colonized vagina to the neonate at or shortly before delivery. Maternal colonization rates range from 15 to 35 percent and can be persistent or intermittent. Preterm (i.e., before 37 weeks' gestation) neonates are at higher risk for early-onset disease.

Perinatal GBS infection includes bacteremia, endometritis, chorioamnionitis, and urinary tract infections, and infection of the neonate. Risk factors for early-onset GBS disease in the neonate include gestational age under 37 weeks, maternal fever greater than or equal to 38°C during labor, prolonged rupture of membranes (≥18 hours), previous sibling with invasive GBS, GBS bacteriuria during current pregnancy, young maternal age (< 20 years), intrauterine fetal monitoring, and low maternal levels of anticapsular antibody.[13] Once infected, the neonate may remain colonized with GBS for several months following treatment and 1 to 3 percent of appropriately treated infants may recur.[13] Early and late onset of GBS in the newborn is discussed in more detail in **41. Neonates**.

In November 2010, the CDC revised the 2002 guidelines for the prevention of perinatal group B streptococcal disease. These revisions are evidence-based and endorsed by physician, nursing, and laboratory professional associations (i.e., the American College of Obstetricians and Gynecologists, the American Academy of Pediatrics, the American College of Nurse-Midwives, the American Academy of Family Physicians, and the American Society for Microbiology). Key changes in the 2010 guidelines

expand laboratory collection and testing methods, improved identification and treatment for women with penicillin allergy, and made changes to the newborn management algorithm (in relation to the risk for early-onset GBS disease). Some of the key changes made from the 2002 guidelines are summarized in Table 43-2. The reader is advised to read the entire CDC 2010 guidelines for comprehensive understanding and guidance.[21]

Table 43-2 Summary of Key Changes from the 2002 Guidelines Regarding Prevention of Perinatal Group B Streptococcal Disease

	Strength of Recommendation
Identification of Candidates for Intrapartum Antibiotic Prophylaxis Universal Screening for GBS	
Guidance regarding cesarean deliveries performed before onset of labor on a woman with intact amniotic membranes is clarified as applying to cesarean deliveries performed at any gestational age.	CIII
In settings in which NAAT for GBS is available, obstetric providers can choose to perform intrapartum testing of vaginal-rectal samples from women with unknown GBS colonization status and no intrapartum risk factors (temperature of ≥100.4°F [≥38.0°C] or rupture of amniotic membranes ≥18 hours) at the time of testing and who are delivering at term.	CII
If an intrapartum risk factor subsequently develops, antibiotic prophylaxis should be administered regardless of the intrapartum testing results.	AIII
Women with positive intrapartum nucleic acid amplification tests (NAAT; which are optional and might not be available in all settings).	AII
Intrapartum Antibiotic Prophylaxis *The definition of high risk for anaphylaxis is clarified as a history of anaphylaxis, angioedema, respiratory distress, or urticaria following administration of penicillin or a cephalosporin.*	
The recommended dosing regimen of penicillin G is 5 million units intravenously, followed by 2.5 to 3.0 million units intravenously every 4 hours (recommended to achieve adequate drug levels in the fetal circulation and amniotic fluid while avoiding neurotoxicity).	AIII
Erythromycin is no longer an acceptable alternative for intrapartum GBS prophylaxis for penicillin-allergic women at high risk for anaphylaxis.	
Threatened Preterm Delivery *Separate algorithms are presented for GBS prophylaxis in the setting of threatened preterm delivery: one for spontaneous preterm labor and one for preterm premature rupture of membranes.*	
GBS prophylaxis provided to women with signs and symptoms of preterm labor should be discontinued if it is determined that the patient is not in true labor.	AI
Antibiotics given to prolong latency for preterm premature rupture of membranes with adequate GBS coverage (specifically 2 g ampicillin administered intravenously followed by 1 g administered intravenously every 6 hours for 48 hours) are sufficient for GBS prophylaxis if delivery occurs while the patient is receiving that antibiotic regime.	CIII
Oral antibiotics alone are not adequate for GBS prophylaxis.	DII

GBS Specimen Collection and Processing *Specimen transport options and timing until processing are clarified.*	
GBS identification options are expanded to include a positive identification from chromogenic media and identification directly from enriched broth. NAAT, such as commercially available PCR assays, can also be used after enrichment, if laboratories have validated NAAT performance and instituted appropriate quality controls.	CII
A direct plating option can be included in addition to enriched culture. Direct plating has a lower sensitivity than enriched culture and should not be used as sole means to identify GBS.	CII
Testing for inducible clindamycin resistance should be performed on antenatal GBS isolates that are susceptible to clindamycin, resistant to erythromycin, and are from penicillin-allergic women at high risk for anaphylaxis.	CIII
Laboratories should report GBS in urine culture specimens when present at concentrations of $\geq 10^4$colony-forming units/mL in pure culture or mixed with a second microorganism.	AII

Patients with GBS are to be cared for using Standard Precautions. During nursery outbreaks, cohorting of ill and colonized infants is recommended. Good hand hygiene practices is the best way of preventing the spread of GBS to other infants.13

LISTERIA MONOCYTOGENES

*Listeria monocytogenes*is a facultative anaerobic, nonspore-forming, motile, Gram-positive bacillus found widely in the environment (soil, water) and causes disease in domestic livestock. Foodborne transmission of this organism is responsible for outbreaks (most recently involving soft cheeses and cantaloupe) and sporadic cases of infection. Foods most often involved include unpasteurized milk, soft cheeses, prepared meats (e.g., frankfurters, deli meats, pate), undercooked poultry, unwashed raw vegetables, and smoked seafood. Although transmission is primarily foodborne, healthcare-associated nursery outbreaks have been reported. The incubation period is variable, ranging from 1 day to more than 3 weeks.13

Manifestations of listeriosis infection are host-dependent and disease in the mother may be subclinical or present with fever or an influenza-like syndrome. Listeria bacteremia in pregnant women may result in stillbirth, miscarriage, or premature delivery. Infected newborns face serious outcomes with high morbidity and mortality. Risk factors for severe disease include renal or hepatic disease, corticosteroid therapy, cancer chemotherapy, decreased cell-mediated immunity, HIV infection, and pregnancy. Fetal and perinatal infection result from transplacental transmission, ascending spread from vaginal colonization, or exposure during delivery. Newborn disease is classified as early onset or late onset. Early-onset disease (probably acquired in utero) can present as pneumonia, sepsis, or multiple organ involvement (granulomatosis infantiseptica). Late-onset disease usually presents as meningitis and can result from acquisition of the organism during delivery or from environmental sources.13

To prevent disease, pregnant women should be counseled to avoid consuming unpasteurized dairy products, soft cheeses, and delicatessen foods (prepared salads, meats, cheeses); to thoroughly wash raw produce, such as fruits and vegetables before eating, cutting, or cooking them; and to thoroughly cook ready-to-eat foods (e.g., frankfurters).13

Laboratory diagnosis is performed on cultures of blood, cerebrospinal fluid, or stool. A laboratory technique of cold enrichment may be used for tissues contaminated with normal flora (e.g., placental

tissue) because the organism will grow at refrigerator temperatures (4°C, or 39°F), whereas other bacteria will not. The laboratory should be informed if this organism is suspected. Gram stain of gastric aspirate from an infected newborn may show the organism.[13]

Recommended therapy for severe listeriosis is ampicillin plus gentamicin. Antibiotic therapy for infection diagnosed in pregnancy may prevent fetal or perinatal infections. Listeriosis is a notifiable disease in the United States and Canada. Identified cases should be reported in a timely fashion to your local public health department to facilitate early recognition and control of common-source outbreaks. Patients with listeriosis are to be cared for with Standard Precautions.[13]

CYTOMEGALOVIRUS

Humans are believed to be the only reservoir for cytomegalovirus (CMV). Transmission occurs by person-to-person contact, contact with infectious body fluids (e.g., urine on a diaper), contact with fomites (e.g., a child's toy that has infectious virus on it), or by blood transfusion.[22]Most people in developing countries are seropositive before adolescence. In the United States, 50 to 80 percent of adults have been infected with CMV by the time they are 40 years old. Approximately 50 percent of pregnant women have antibodies to CMV. After the initial (primary) infection, the virus becomes latent and may reactivate.[22]

Person-to-person transmission of CMV requires intimate exposure by mucosal contact with infectious tissues, secretions, and excretions.[22]The virus is intermittently excreted in urine, saliva, breast milk, and genital secretions. Most transmission of CMV in North America is through sexual contact. CMV may also be introduced into families by newborns or toddlers attending day care centers, where prevalence rates may be high. Vertical transmission can occur as a result of in utero transplacental passage of maternal bloodborne virus, at birth from ingestion of infected genital tract secretions, or postnatally by ingestion of CMV-positive breast milk. Transmission can result from transfusion of blood from a seropositive donor to a seronegative recipient.[13]

A review and meta-analysis of congenital CMV infections provides combined data from 34 studies.[23]Of live asymptomatic newborns, 0 to 4.4 percent were CMV positive, making CMV infection the most common congenital viral infection. The overall birth prevalence of symptomatic congenital CMV was 0.07 percent. The rate of transmission from mother to fetus is greatest at the time of maternal primary infection, at 32 percent, whereas the recurrent infection transmission rate was 1.4 percent. Sequelae are more severe following primary maternal infection. About 10 to 20 percent of newborns infected at the time of primary maternal infection will develop deafness or neurological sequelae.[13]

Because there is neither a vaccine for prevention of infection nor effective therapy for acute maternal infection, routine serological screening of women and newborns is not recommended. Testing is generally limited to women in whom a CMV exposure is suspected. Active infection with CMV can be diagnosed by polymerase chain reaction (PCR) or viral culture of CMV from urine, saliva, throat swab specimens, or other body tissues. The most accurate method to document primary maternal infection is to establish that seroconversion has occurred. A positive test for CMV immunoglobulin G (IgG) indicates that a person was infected with CMV at some time during his or her life but the presence of CMV IgG cannot determine when a person was infected. However, if antibody tests of paired acute- and convalescent-phase serum samples show a fourfold rise in IgG antibody and CMV immunoglobulin M (IgM) antibody is present or CMV virus has been cultured, an active CMV infection is present. Isolation

of the virus or detection of the CMV genome by PCR from either amniotic fluid or fetal blood is the most sensitive test to detect fetal CMV infection.[13] The virus may be found in the urine, saliva, blood, or other body tissues within 2 to 3 weeks after birth. Antibody tests cannot be used to diagnose congenital CMV.

To prevent transmission of CMV, healthcare personnel should not transfuse high-risk CMV-seronegative persons (e.g., premature neonates) with CMV-positive blood.[13] They should take care, using Standard Precautions, when handling used diapers and changing newborns,[6,13] and practice good personal hand hygiene.[13,22] Mothers with newborns or toddlers in day care centers should be counseled regarding the risk for transmission and good hand hygiene during diaper changes. Patients with CMV should be cared for with Standard Precautions.[13,22]

HEPATITIS B VIRUS

Part of the strategy for prevention of HBV infection includes routine screening of all pregnant women and appropriate immunoprophylaxis of infants born to HBsAg-positive women, infants born to women with unknown HBsAg status, and universal immunization of infants beginning at birth.[13]

Testing is recommended for all pregnant women as a part of routine prenatal care; those not tested prenatally or at increased risk should be tested upon admission for delivery. Results should be documented in their medical record and available at delivery. Vaccine should be offered to at-risk HBsAG-negative women (e.g., injection drug users, women with recurrent STIs), household contacts, and sexual partners of those who are chronic carriers.[6,13]

HBV (chronic or acute infection) is spread through contact with blood or bodily fluids (e.g., blood, vaginal secretions, and amniotic fluid)[6,13] and transmitted to the newborn through exposure to maternal blood during the birthing process. Perinatal transmission is common, especially when HBV-infected women are also Hepatitis B e antigen (HBeAg)-positive. The rate of transmission from a woman who is Hepatitis B surface antigen (HBsAg)-positive and HBeAg-positive to her newborn are 70 to 90 percent. Women who are HBsAg-positive and HBeAg-negative have a transmission rate of 5 to 20 percent. More than 90 percent of infected newborns will develop chronic HBV infection without proper postexposure prophylaxis.[6,13] More information can be found in **41. Neonates** and **97. Viral Hepatitis**.

HBsAg has been detected in milk from HBsAg-positive women. However, studies have indicated that breastfeeding by HBsAg-positive women does not increase significantly the risk of infection to their newborns. All infants born to known
HBsAg-positive women should receive Hepatitis B immunoglobulin and HBV vaccine within 12 hours of delivery, complete the recommended series of Hepatitis B vaccine, and should be tested after completion of the vaccine series (age 9 to 18 months) to determine if the vaccine worked and the infant is not infected with HBV through exposure to the mother's blood during the birth process. Women should receive education on nipple care to prevent cracking and bleeding.[13]

Laboratory diagnosis is accomplished by detection of HBsAg in the serum. Patients with HBV are to be cared for using Standard Precautions. Additionally, all healthcare personnel who may be occupationally exposed to blood or body fluids should be immunized against HBV.[13]

HEPATITIS C VIRUS

Primarily, HCV transmission occurs via parenteral exposure to HCV-infected blood, blood products, or items/devices contaminated with infected blood and vertically from mother with HCV infection to child (approximately 2 to12 percent). In contrast to HBV, sexual and vertical transmission is inefficient.[6]

Although routine screening for HCV is not recommended in pregnancy, women who should be screened and tested include those at increased risk for infection such as those with injection drug use, percutaneous exposure from occupation or recreation, mucosal surface blood exposure, and those seeking evaluation for STI, including HIV or are known to be at risk or are HIV positive. This risk directly correlates with HCV ribonucleic acid (RNA) levels (i.e., the higher the level of HCV RNA, the greater the risk of transmission to the newborn). Coinfection with HIV increases the levels of HCV RNA and therefore, the risk for vertical transmission. HCV is not a contraindication for breastfeeding,[6]but women should consider abstaining if their nipples are cracked and bleeding.[13]

HERPES SIMPLEX VIRUS

Genital HSV infection is caused by both HSV-1 (20 to 50 percent)[24]and HSV-2. Most infections are asymptomatic. When an individual with no HSV-1 or HSV-2 antibody acquires either virus in the genital tract, it will produce a first-episode primary infection. If a person with preexisting HSV-1 antibody acquires HSV-2 genital infection (or vice versa), a first-episode nonprimary infection will be produced. Following the initial infection, the virus resides in the proximal nerve fiber in a latent state. Reactivation of the latent virus produces a migration back to the skin and mucosal surfaces and produces a recurrent infection.[6,24]

Women who are actively shedding virus are at high risk for transmission to the neonate.[25]The majority (85 percent) of infections occur during birth in the peripartum period, whereas 5 percent of infections occur before birth and 10 percent may occur after birth through a maternal or nonmaternal source.[24]

The highest risk for peripartum transmission is when women with primary HSV infection or nonprimary first-episode infection late in pregnancy give birth vaginally (30 to 50 percent), whereas the transmission risk is less than 2 to 5 percent in women delivering vaginally with recurrent infection.[6]

Neonatal HSV is a serious condition, and even with early treatment is associated with significant morbidity and mortality. Clinical presentation ranges from:[13,24]

- Disease localized to the skin, eye, and mouth (83 percent)
- Central nervous system involvement with or without skin involvement (63 percent)
- Disseminated infection (multiorgan involvement) (58 percent)

If skin lesions are absent, the diagnosis can be difficult but should be included in the differential diagnosis of a septic infant.[13]

To prevent transmission, healthcare personnel should examine the woman for presence of active lesions or report of prodrome at time of admission for delivery. If lesions or prodrome are present, delivery should be accomplished by cesarean section. The majority of specialists recommend that women with recurrent genital herpetic lesions at the onset of labor deliver by cesarean section to prevent neonatal herpes, but cesarean section does not completely eliminate the risk for HSV transmission to the infant.[6,24]The benefit of cesarean section decreases with every increase in the length of time that the

membranes have been ruptured. In the case of PPROM, remote from delivery and where expectant management is elected, consideration should be given to using an antiretroviral medication.[6] After birth, the mother and baby should be cared for using Contact Precautions and the mother should be instructed to be diligent with hand washing before and after caring for the infant. Local newborn infection may result from use of a fetal spiral electrode for fetal heart rate monitoring in women with a history of herpes, even when lesions are not present (i.e., asymptomatic viral shedding). Therefore, the benefit of fetal scalp monitoring must be carefully considered against the risk in women who have a history of recurrent HSV and no active lesions.[6] If the woman has active HSV, fetal spiral electrodes should not be used because the electrode site (scalp) can become a point of entry for the virus to the fetus.

Maternal understanding of spread of the virus is necessary to protect the newborn or other newborns. It is of utmost importance that parents are taught the signs and symptoms of active HSV as well as measures to protect the infant from acquiring the infection. These measures need to emphasize hand hygiene and covering of extra-genital lesions. Additionally, persons with active cold sores should not kiss the newborn. The mother or visitor with oral lesions may wear masks. Parents with active lesions must be instructed not to handle other newborns during their stay in the hospital. Infected family members must also observe precautionary measures when handling the newborn. Neonatal transmission from infected parents has been documented. Breastfeeding is permitted, unless lesions are present on the breast and provided that reasonable care is taken.[13]

Newborns should be observed carefully for signs and symptoms of infection. Infection may occur as late as 4 to 6 weeks after delivery. Parents and staff should therefore be educated about signs and symptoms of neonatal herpes (e.g., lethargy, poor feeding, fever, lesions which may or may not be present, seizure). Asymptomatic infection in neonates occurs rarely, if ever.[13]

Maternal infection is diagnosed by PCR or virus culture of skin, mucosal lesions, or cervix. Direct immunofluorescence assay, PCR, and culture of newborn skin lesions should be done if present. Conjunctival swabs, mouth swab, and nasopharyngeal and rectal specimens from the newborn for HSV culture or PCR should be obtained 24 to 48 hours after birth. If there is suspicion for clinical disease, cerebrospinal fluid and blood can be rapidly analyzed by PCR.

Staff with cold sores should not care for neonates if possible, but if patient care is compromised, this must be weighed against transmission risk. In this case, lesions should be covered and staff should avoid touching the lesions and must adhere to strict hand hygiene. Transmission from staff with active genital herpes is unlikely, but care should be taken to diligently follow hand hygiene policies. Staff with herpetic whitlow should not care for neonates or immunocompromised patients.[13]

HUMAN IMMUNODEFICIENCY VIRUS

HIV is transmitted parenterally, sexually, and vertically. Vertical transmission depends on the stage of maternal disease (early versus late disease), viral load, viral strain, and breastfeeding. HIV transmission from mother to child can occur during pregnancy, at delivery, or as a result of breastfeeding. The decline in transmission rates is multifactorial and includes the implementation of recommendations for universal prenatal HIV counseling and testing, antiretroviral prophylaxis, use of scheduled cesarean delivery prior to labor and rupture of membranes, and avoidance of breastfeeding for mothers with HIV infection.[6,13] Perinatal HIV transmission rates have since dramatically decreased to less than 2 percent in

the United States and Europe.[15] Risk factors believed to increase the risk for vertical transmission include the amount of exposure to virus (e.g., high maternal viral load and advanced maternal clinical disease), duration of exposure from intrapartum events (e.g., prolonged rupture of membranes, vaginal delivery), and duration of breastfeeding.[13,26] Recommendations regarding the treatment of pregnant HIV-infected women in the United States have evolved rapidly, and an increasing proportion of women are now receiving highly active combination antiretroviral therapy throughout pregnancy to decrease the viral load, which in turn will decrease transmission risk.[13,26]

During labor, internal fetal heart monitoring (e.g., spiral electrode/scalp clip), scalp pH sampling, intrauterine pressure measurements, and artificial rupture of membranes should be avoided.

Breastfeeding is a risk factor for postpartum HIV transmission to the breastfeeding newborn. HIV has been detected in breast milk, and transmission by this route has been documented. In countries where a safe alternative to breast milk is available, women who are HIV positive should not breastfeed their newborns, to prevent HIV transmission.[13,26] In countries where there are safe alternative sources of feeding that are readily available, affordable, and culturally acceptable, HIV-infected women should be counseled not to breastfeed their newborns or to donate to milk banks.[6,13] Newborns born to HIV-positive women are to be followed for 18 months to assess for HIV infection.[13,26] Patients who are HIV positive are to be cared for with Standard Precautions.

Readers are encouraged to visit **http://www.aidsinfo.nih.gov** for updates on recommendations.[15]

HUMAN PARVOVIRUS B19

Approximately 50 percent of pregnant women are immune to parvovirus B19. Transmission is via respiratory droplets and maximum communicability occurs before onset of rash. The individual is not infectious after the rash appears.

The major target of B19 infection is red cell precursors and the presence of the P antigen on these cells.[25] This, combined with rapid turnover of these cells in the fetus, makes it especially vulnerable for lytic infection, causing severe fetal anemia resulting in fetal hydrops and death. B19 infection can also cause intrauterine growth retardation and isolated pleura and pericardial effusions but there are no reports of congenital malformations. Most reported maternal infections that have resulted in fetal death occurred in the first half of pregnancy, and fetal death and spontaneous abortion usually occur 4 to 6 weeks after infection. The transplacental transmission rate of infection is about 30 percent, and the incidence of fetal loss has been reported to be 2 to 6 percent.[13]

Significant efforts in laboratories have focused on the use of molecular and serological tests to differentiate between acute, past, or chronic B19 infection. In an exposed pregnant woman, the laboratory should test for presence of maternal IgM because a positive PCR test is not always indicative of acute infection and false-negative PCR tests may occur because of genotype variants. In the fetus, an ultrasound should be performed for assessment of damage to the fetus.[13] Alternatively, an amniocentesis can be done to obtain a specimen for parvovirus PCR.

Susceptible women who are pregnant or may become pregnant and experience continued exposure to the virus at home, at school, or at a healthcare facility should be counseled regarding the risk to the

fetus and methods of reducing transmission (e.g., hand hygiene). Women with sick children at home should practice meticulous hand hygiene and not share food utensils.[13]

For most patients, supportive treatment is all that is required. Fetal hydrops is treated with intrauterine transfusion. This treatment option makes it important to diagnose acute parvovirus infection during pregnancy when significant exposure has been documented or infection is suspected.

Most patients with B19 infection are to be cared for with Standard Precautions. Droplet precautions may be required for hospitalized children with aplastic crises or for immunosuppressed patients with chronic infection and anemia.[13]Pregnant healthcare personnel should be counseled regarding risk to the fetus and methods of reducing transmission through consistent use of Standard Precautions and hand hygiene. See **88. Parvovirus** B19, for additional information.

VARICELLA-ZOSTER VIRUS

Varicella-zoster virus (VZV) is a member of the herpes group viruses, and as such, it is able to reside latently in the body and reactivate occasionally. VZV can be propagated in culture but is labile compared with HSV. PCR and IgM serology are therefore the diagnostic tools of choice in the laboratory. Varicella (chickenpox) is the manifestation of primary infection with the virus and results in a pruritic, generalized, vesicular rash with lesions at various stages followed by crusting. Complications include systemic infection, bacterial superinfection, pneumonitis, and central nervous system infection. Children often have milder symptoms than adolescents. Adults may suffer only a few lesions, or the presentation can be quite severe. Shingles (herpes zoster) is the reactivated form of the virus and has a dermatomal distribution, with a crop of vesicles containing infectious virus. Shingles can be very painful and may become disseminated in the immunocompromised or HIV-infected host.[13]

Varicella is highly contagious. Transmission occurs horizontally via respiratory droplets, airborne route, and contact with vesicle fluid. Transmission can also be vertical. A fetus exposed to varicella before 20 weeks' gestation has approximately a 2 percent risk for developing congenital varicella syndrome, characterized by limb atrophy, malformed digits, and cutaneous scars. The central nervous system and eyes may also be involved, resulting in seizures, developmental delays, microcephaly, bowel or bladder sphincter dysfunction, chorioretinitis, cataracts, and microphthalmia. During the second 20 weeks of gestation, the newborn can develop unapparent varicella and subsequent zoster early in life without having experienced extrauterine varicella. Varicella infection can be fatal for a newborn if the mother develops varicella between 5 days before delivery and 2 days after delivery. If the mother develops varicella more than 5 days before delivery and the newborn's gestational age is 28 weeks or greater, the impact of the severity of the disease for the newborn is lessened by the transplacental transfer of maternal VZV antibody.[13]

Prevention of maternal varicella includes vaccination of girls before they reach childbearing age, plus assessment of the woman's varicella susceptibility preconceptually and offering varicella vaccine if she is susceptible. An assessment of the mother's varicella susceptibility should also be done prenatally. Counseling of the susceptible woman to avoid exposure to individuals with varicella or zoster and vaccination of close contacts of the susceptible woman of childbearing age should also be done. Varicella-zoster immunoglobulin (VariZIG) should be given as soon as possible but, to be effective, within 10 days of the exposure.[13]VariZIG prophylaxis should be provided to the following patients:

- Exposed susceptible pregnant women (however, provision of VariZIG may prevent infection in the woman, but may not protect the fetus)

- Newborns of women with onset of varicella within 5 days before delivery to 2 days after delivery
- Exposed, hospitalized, premature newborns (> 28 weeks' gestation) of women lacking a reliable history of varicella or serological evidence of immunity to varicella
- Hospitalized premature newborns younger than 28 weeks' gestation or under 1,000 g birth weight, regardless of maternal varicella history or VZV serostatus[13]

Laboratory diagnosis is usually not required. If there is confusion regarding the etiology of the rash, vesicle scrapings from the woman or neonate may be examined by direct fluorescence microscopy or PCR, which allows same-day results.

Airborne and Contact Precautions are to be used when caring for a woman with varicella and for a newborn born to a woman with varicella. If the newborn remains hospitalized, these precautions must remain in place until 21 days of age. If the newborn has been given VariZIG, the precautions must remain in place until the newborn is 28 days old.[13]

See **80. Herpes Virus** for additional information on VZV.

The Intrapartum and Early Postpartum (Predischarge) Periods

ADMISSION PROCESS AND INITIAL ASSESSMENT

Initial admission communicable disease assessment of the patient is an essential component of supporting an infection-free, family-centered maternity care model. Furthermore, with the increase of MDROs such as MRSA and VRE, it is prudent to use a verbal screening tool to determine risk factors for MDRO carriage. If the risk factors are high, swabs for MRSA and VRE should be obtained so that appropriate isolation precautions for mother and the newborn baby can be implemented. The patient and her family must be aware that they share accountability for ensuring that their visitors are free of infection when they visit.

The admission assessment should include questions regarding recent exposure to any communicable diseases, risk for social or behavioral exposures (e.g., age less than 25, STIs, substance use, multiple sexual partners, homelessness/shelter residence) and a review of any chronic infections she may have (e.g., prenatal screening results) to ensure that necessary interventions are made. This allows the initiation of appropriate precautions, interventions, and health teaching. Policies and procedures should be in place to provide for triaging patients into appropriate precautions in a timely manner to prevent any possible exposure to communicable diseases to healthcare providers and other patients (e.g., febrile respiratory illnesses, tuberculosis, gastroenteritis, shingles, varicella [chickenpox], scabies, lice, fever of unknown origin).[6]

Some examples of appropriate precautions would include the following:

- If the woman or family member has had a recent exposure to varicella (chickenpox), the woman's immunity to chickenpox must be verified so that precautions can be taken, if required.
- If the woman and/or family members are prone to cold sores, the health education will include (1) reminding the person not to kiss the newborn during the prodrome and the period that the cold sore is present and (2) reinforcing the need for hand hygiene before touching the newborn, particularly when a cold sore is present.[13]

Initial screening should also include verification that prenatal screening tests have been completed. If the result of serological testing for HBsAg is unknown, the reader is referred to the HBV section of this chapter.[6]

RISK FACTORS FOR DEVELOPMENT OF HEALTHCARE-ASSOCIATED INFECTION IN WOMEN AND NEWBORNS

Host Factors

Maternal host risk factors that increase the risk of a postpartum infection in both the woman and newborn include the following:

- Immunosuppression (e.g., steroids)
- Uncontrolled diabetes
- Nutritional status, either a low or high (<19 or >30) body mass index (BMI)
- American Society of Anesthesiologists score of three or greater
- Low socioeconomic status
- Smoking, which delays primary wound healing and may increase the risk of primary wound infection in women who have had cesarean sections[27]
- Specific vaginal colonization/infections, such as urinary tract infection, GBS, and bacterial vaginosis (BV), which may increase the risk of premature rupture of membranes/preterm labor, chorioamnionitis, and postpartum endometritis
- Specific colonizations and infections that require specific prophylaxis and treatment to prevent an infection in the newborn (e.g., GBS, HIV, HSV, syphilis, gonorrhea, chlamydia)
- Patients with high BMI, poor nutritional status, or diabetes
- Ruptured membranes, which can be either the cause or consequence of infections[6]
- Preterm labor, which may indicate intra-amniotic infection even before ROM[6]
- Prolonged prenatal hospital stay[27]

In addition to host risk factors and the infections previously reviewed, the following labor-associated risk factors increase the risk for an infection:

- Preterm labor
- Premature ROM
- Prolonged ROM (usually considered longer than 24 hours)
- Prolonged labor
- Multiple vaginal examinations
- Use of internal monitoring
- Cesarean delivery
- Chorioamnionitis

All policies and procedures used for providing care throughout the pregnancy and postpartum period must be reviewed to verify that the recommended aseptic technique, standards for reprocessing of

equipment, and Standard Precautions are used consistently.

Rupture of Membranes

Premature rupture of membranes (PROM) occurs prior to the onset of labor and at-term is usually a part of the normal physiologic process leading to labor and delivery. If ROM happens before 37 weeks of completed gestation (PPROM), it can be from pathologic mechanisms (single or multiple). PROM increases the potential for infection and is a major cause of perinatal morbidity and mortality.

Interventions

Multiple Vaginal Examinations

Multiple vaginal examinations can introduce vaginal or intestinal organisms into the uterus.[28] Digital examination of the cervix should be avoided until active labor occurs or until a decision has been made to induce labor. Although minimizing the number of vaginal examinations and attention to clean technique is standard care, it is even more important when the woman has ROM and diagnosed presence of infection (GBS, chorioamnionitis). Healthcare providers should avoid unnecessary examinations and monitor and record their frequency. Sterile water-soluble lubricants may be used to decrease discomfort during vaginal examinations. Antiseptics such as povidone-iodine or hexachlorophene should not be used, as they are absorbed via the mucous membrane.[6]

Internal Monitoring

Internal pressure catheters may be used for monitoring contractions. Internal monitoring can lead to an intra-amniotic fluid infection and/or endometritis in the mother. Internal fetal electrodes may be used to monitor the fetal heart rate. Careful placement on the fetus's scalp is important to prevent an abrasion that creates a portal for maternal organisms to enter the scalp (e.g., HSV; bloodborne pathogens such as HBV, HCV, and HIV). Prevention of infection includes careful placement of the catheter with aseptic technique. Single-use disposable products are preferable to transducers.

Prolonged Labor

Induction of labor may pose a risk for infection due to prolonged ROM, the risk for chorioamnionitis, and increased measures to monitor labor progress such as multiple vaginal exams.[6]

Use of Forceps for Delivery

Forceps should be thoroughly cleaned and sterilized according to reprocessing standards before use. Aseptic technique should be followed when using the forceps.[6]

Manual Placental Removal

Manual removal of the placenta may be necessary if the placenta is retained. Complications associated with manual removal are infection and bleeding. A Cochrane Review (2011) concluded that consideration for prophylaxis should be done on a case-by-case basis, as there are no clinical trials showing a benefit from routine antibiotics prior to removal of the placenta.[29]

Noninvasive Interventions

Noninvasive interventions such as stress tests, Doppler ultrasonography, and ultrasonography are frequently used. Single-use belts are preferred. In areas where belts must be reused, ensure appropriate cleaning occurs between each patient use (e.g., laundering). The management and dispensing of the ultrasound gel before or as part of any procedure are to be carefully managed, because nonsterile gel has been implicated in outbreaks when used on nonintact skin. Ultrasound bottles should not be topped off or refilled and should be discarded when empty.[30]

Cesarean Section

There is an increased risk for postpartum infection following a cesarean delivery. The circumstances leading to the procedure and whether it is a planned, elective cesarean delivery with intact membranes or an emergency cesarean delivery with ruptured membranes present different risks for infection. The classification of the surgical procedure or cesarean delivery will affect the infection rate because there is a higher risk with ruptured membranes.[27] The host factors and management of the interventions used intrapartum also influence the risk for a postoperative surgical infection. Hospitalization postpartum is prolonged following a cesarean delivery, which can be a risk factor for an HAI.

To decrease the risk for a postoperative surgical infection, healthcare providers should follow the evidence-based recommendations of Mangram et al.[27] and the CDC (see **37. Surgical Site Infection**). It must be verified that prophylactic antibiotics are given as recommended.[27] Healthcare facilities should establish a cesarean delivery surveillance program that includes in-depth analysis of the possible contributing factors for each infection. Analysis of the aggregate data must be communicated to the appropriate personnel to review so that the indicated interventions can be implemented and monitored for effectiveness. The surveillance program should follow the woman for 30 days postpartum, as most infections are identified after discharge. The operative factors that should be assessed to verify that guidelines are being followed include (1) duration of surgical scrub, (2) skin antisepsis at the operative site, (3) management of hair removal (if necessary), (4) duration of the procedure, (5) surgical classification of the procedure indicating the amount of contamination at the site, (6) operating room ventilation, (7) cleaning and sterilization of instruments, (8) Standard Precautions, and (9) dress code. The surgical team's technical skill will impact the risk of infection. Poor hemostasis, failure to obliterate dead space, and tissue trauma all increase the risk for infection. If a hematoma develops, the risk for postoperative surgical site infection increases. Antibiotic prophylaxis is recommended for all cesarean deliveries and should be administered within 60 minutes prior to cesarean delivery unless the woman is already receiving adequate antibiotic therapy (e.g., for chorioamnionitis). In emergent cases, antibiotic prophylaxis should be given as soon as possible after delivery.[6] Prophylaxis for GBS management differs from that given to prevent maternal postoperative infections following a cesarean section. These antibiotic protocols are not to be confused.

Emergency cesarean deliveries are not infrequent; therefore, presetting of operative tables is not recommended.[8] The Association of Perioperative Registered Nurses guidelines regarding the maintenance of the sterile field, surgical skin preparation, and the use of clipping versus shaving for hair removal should be followed.[8]

Anesthesia

Skin preparation and sterile technique must be done carefully to prevent an infection from spinal or epidural anesthesia.[6] Healthcare personnel are urged to limit or eliminate the use of multidose vials

wherever possible to prevent the risk of contaminating vials. Vials must be managed safely to prevent any risk for cross-infection or bloodborne exposure from a contaminated vial. Personnel administering and providing support activities for the woman receiving regional anesthesia/analgesia during labor should wear caps and masks.[31] In October 2005, the Healthcare Infection Control Practices Advisory Committee reviewed the evidence and concluded that there is sufficient experience to warrant the additional protection of a face mask for the individual placing a catheter or injecting material into the spinal or epidural space.[31]

Perineal Care Intrapartum and Postpartum

Cleansing of the vulva, perineum, and anal region with warm, soapy water should be done before and after delivery. This should be done using a downward and backward motion so that fecal organisms will not be introduced into the genital tract. Once the woman is positioned for delivery, the vulva should be washed thoroughly with soap and water. Antiseptics have not been shown to decrease the acquisition of infection during the intrapartum period.[6]

Dress Code

A dress code policy for labor, delivery, cesarean delivery, and the nursery should be established.[6,8,27]

Healthcare providers who are involved in the delivery are to wear gloves, gowns, surgical masks, caps, and eye protection during the procedure. All personal protective wear must be worn correctly so that it protects the healthcare provider and the woman and newborn. Masks are to cover the nose and mouth and to be discarded as soon as they are removed. For surgical procedures, all personnel who have direct contact with the sterile field during vaginal deliveries, obstetrical surgical procedures, and surgical procedures in the nursery should wear sterile, long-sleeved gowns.[6] As potential exposures to amniotic fluid and blood can occur during the delivery, wearing aprons or gowns made of impervious material is recommended to protect the healthcare provider from body fluid exposure. Protective wear should also shield the legs and feet from body fluid exposure, because there is often extensive body fluid contamination during a cesarean delivery.

Family or support members attending a cesarean should either wear scrubs or disposable scrub suits. Consideration should be given to establish dress codes for support persons involved in water births.

Gloves should be worn when handling the placenta or the neonate until blood and amniotic fluid have been removed from the newborn. Care providers should wash hands before gloving and after removing gloves and immediately wash any skin surfaces that become contaminated with body fluids.

Caps, beard covers (for bearded persons), and masks should be worn during certain surgical procedures, such as umbilical vessel catheterization in the newborn.[6]

The wearing of cover gowns by regular healthcare providers in nurseries has not been shown to decrease infections. If the nursery healthcare providers are holding the newborn, a long-sleeved gown should be worn over the clothing and ideally discarded after each use. If the gown must be reused, it is to be used exclusively for the care of that newborn. Strict hand hygiene must be enforced for all personnel and family members handling the newborn to protect the newborn.[6]

Request for Placenta by Family

Some cultures include traditions regarding the ingestion or disposal of the placenta.[32] There should be a policy and procedure in place to address such requests. State and local health regulations regarding the requirement for pathology review and disposal of human tissue must be followed.

Visiting Policies

The perinatal program should have a policy regarding family and other visitors. The policy may limit, restrict, or deny visitation when the risk of infection transmission overrides the importance of visitation. The designated support person for the woman is encouraged to remain throughout the intrapartum and immediate postpartum periods. In most circumstances, parents of newborns should have unrestricted access to the newborn. Flexible visiting hours for parents to feed, handle, and hold the newborn, even if in an intensive care setting, should be encouraged. Some units offer sibling classes to prepare the other children in the family for the birth. The presence of siblings may be appropriate in labor, at delivery, or in postpartum if the child is supervised and the local authorities permit. This is an opportune time to teach the parents to share responsibility of preventing exposure of their newborn to visitors or siblings that have communicable infections by asking them to not visit until they are well. The health teaching of the parents should also include asking them to remind anyone who handles the newborn to wash his or her hands before handling the newborn.

Other Concerns

To prevent urinary tract infections (UTIs), catheterization should be avoided whenever possible, with healthcare providers making every effort to assist the patient in voiding spontaneously. If she is unable to void, a single catheterization may be necessary. If the patient experiences continued difficulty voiding postpartum, the use of a single indwelling catheter is preferable to repeated catheterizations[6] (see **33. Urinary Tract Infection**). Bladder management postpartum must be attentive, because urinary retention is common and may lead to a UTI. Women should be encouraged to void as soon as possible after delivery and to ensure adequate emptying of the bladder. The woman should be checked frequently during the first 24 hours after delivery, with particular attention to displacement of the uterine fundus and any indication of the presence of an extended bladder above the symphysis.

In general, healthcare personnel should monitor for symptoms of infection postpartum (e.g., elevated temperature, chills, breasts redness, excessive tenderness or discomfort, leg pain, wound drainage, increased lochia or vaginal bleeding[6]) via monitoring temperature; assessing color, odor, and amount of lochia; observing the perineum/incision for induration swelling or drainage; and observing.

Postpartum Care for the Newborn

Cord, skin, and eye care are discussed in **41. Neonates**.

Hand hygiene is to be used before and after holding or caring for a newborn. Readers should refer to the previous section on dress code.

Appropriate skin care for the newborn is important. The first bath should be postponed until the newborn has achieved thermal stability, unless indicated by presence of maternal infection (e.g., HBV, HSV, and HIV).[6] Nursing and medical staff should develop a policy outlining the time of the first bath and the subsequent method of skin cleansing based on evidence-based guidelines.[6]

If a circumcision is being performed, sterile technique must be followed.

Separation of the woman and newborn rarely needs to be done for infection prevention reasons. The healthcare providers of the newborn should be notified if the mother develops a fever during the postpartum period. The need to separate the woman and newborn depends on the agent, the means of transmission, and the susceptibly of the host (Table 43-3).

Table 43-3 Examples of When Separation of the Newborn and Woman Is Recommended

Infection	Comments
Clinical signs and symptoms or abnormal findings of chest radiograph consistent with pulmonary or laryngeal tuberculosis	Mother and infant should be separated until mother has been evaluated and, if tuberculosis disease is suspected, until the mother and infant are receiving appropriate antituberculosis therapy, the mother wears a mask, and the mother understands and is willing to adhere to infection control measures.[13]
Chickenpox	Exposure to chickenpox needs to be assessed on a case-by-case basis.[13]
Herpetic whitlow	Direct/hands-on contact not permitted.[13]
Influenza	Consider separation of mother who is ill with suspected or confirmed influenza from newborn during hospital stay. Optimum length of separation has not been established and should be assessed on a case-by-case basis.[33]

Breast Milk and Formula Feeding

Breastfeeding provides the neonate with many health benefits, including protection against some infectious diseases caused by bacteria, viruses, and parasites, in addition to being the ideal source of nutrition.[13]Human milk contains protective elements such as cells, specific secretory antibodies, and innate factors such as glycoconjugates and anti-inflammatory components. Newborns who are breastfed will have higher concentrations of protective bifidobacteria and lactobacillus in their gastrointestinal tract. The presence of these organisms increases resistance of the intestinal tract to pathogenic organisms.[13]

Although breastfeeding is best for the newborn, breast milk is a body fluid, and there may be times when it is appropriate not to breastfeed. Breast milk is not sterile and may be capable of transmitting bacterial and viral infections.[13]For these reasons, it is imperative that breast milk be handled appropriately from the time of the woman's decision to breastfeed through the collection, storage, and preparation of breast milk feeds, particularly for the premature neonate. These topics are discussed in the following text: reasons for withholding breast milk; hygiene for the woman; collection and storage of expressed breast milk; preparation of feeds (e.g., addition of fortifiers, use of powdered formulas); design of feed preparation rooms; and human milk banking.

REASONS FOR WITHHOLDING BREAST MILK

The only infections in which breast milk must be withheld from the newborn are: (1) presence of a breast abscess (do not nurse on the affected breast and pump and discard until 24 to 48 hours after surgical drainage and appropriate antimicrobial therapy), (2) HSV lesion on breast, and (3) infection with

HIV, or human T-cell lymphotropic virus type I or II.[6,13] If appropriately treated endometritis or mastitis is present, breastfeeding can continue.

Currently, maternal HCV is not considered a contraindication for breastfeeding. The decision to breastfeed in the presence of maternal HCV must be an informed decision made by the woman in consultation with her healthcare provider.[13,24]

Breastfeeding is not contraindicated for infants born to mothers who have uncomplicated maternal fever or chorioamnionitis and seroposivity (not recent conversion) for CMV if the infant is term.[6] Breast milk-acquired CMV infection presenting with CMV sepsislike syndrome is relatively rare but a risk for preterm newborns with birth weight of less than 1,500 grams. Pasteurization or freezing milk at 20°C (–4°F) decreases but does not eliminate CMV reliably.[6]

Women with active, infectious, untreated pulmonary tuberculosis cannot breastfeed because they are to have no direct contact with the newborn. However, breast milk can be pumped and given to the newborn, provided that the treatment the woman is receiving is not a contraindication for breastfeeding. Breastfeeding can be resumed when a mother with tuberculosis has been treated for a minimum of 2 weeks and it is documented that she is no longer infectious.[13]

Mothers acutely infected with H1N1 influenza should temporarily be isolated from their infants until they are afebrile, but they can provide expressed milk for feeding.[33]

The American Academy of Pediatrics has authored several resources for breastfeeding guidance.[34]

HAND HYGIENE FOR THE MOTHER

Whether a woman is breastfeeding or formula feeding, hand hygiene is important. If she has gastroenteritis or a respiratory tract infection, it becomes even more important to avoid transmitting fecal bacteria or viruses to the newborn.

As part of learning about breastfeeding and expressing breast milk, the woman should be taught about the importance of performing hand hygiene every time—before she picks up her newborn to put to the breast and every time she prepares to pump. Otherwise, pathogenic organisms on her hands may contaminate the breast milk.[6]

COLLECTION, TRANSPORTATION, AND STORAGE OF EXPRESSED BREAST MILK

Whether in the hospital or at home, the mother may decide to pump milk to save for future use or to bring to her premature newborn in the hospital. When a woman pumps and stores her milk, throughout the process there are many opportunities for organisms to be introduced or for organisms already present in the milk to be allowed to multiply to levels that are unsafe for the newborn.

The breast pumping kits a woman uses must be carefully washed with hot soapy water after each use. Milk must be collected into a sterile or aseptic, bisphenol free container and refrigerated.[35]

Milk that needs to be transported (e.g., between home and hospital) must be transported at 4°C (39°F). This can be accomplished by the use of freezer packs. The containers of milk must be in a clean,

sealed, plastic bag to prevent external contamination. The CDC follows the recommendation of the Academy of Breastfeeding Medicine for breastmilk storage:[35]

- If stored at room temperature, 16° to 29°C (60° to 85°F), the recommended storage duration is optimally 3 to 4 hours with an extension to 6 to 8 hours if in very clean conditions
- If stored in the refrigerator at ≤ &4°C (39°F), 72 hours is optimal and 5 to 8 days if under very clean conditions
- If stored in the freezer at <17°C (0°F) 6 months is considered optimal and 12 months is acceptable

Refrigerators and freezers used in any facility where breast milk is stored must be monitored (temperature read and recorded) each shift and also have an alarm. The alarm should be triggered if the temperature of the refrigerator or freezer is outside of its range (high or low), alerting an appropriate person to take action. In addition, refrigeration must have adequate capacity to chill sterile-ingredient water and to cool prepared formula to 4°C (39°F) within 1 hour of preparation.[36]

PREVENTION OF BREAST MILK DELIVERY ERRORS

To prevent errors in delivery of expressed breast milk to a hospitalized newborn, women pumping milk must be instructed to clearly label the milk with—at a minimum—the newborn's name and the date the milk was collected. Also, each woman must have an individual bin in which to store her breast milk.[36,37]

A quality assurance (QA) program, designed to decrease the risk for a potential breast milk error and to identify if an error has occurred, must be in place. The QA program may take various forms, including but not limited to (1) a double-labeling system in which one label of the feed is removed from the feed container and placed, as a permanent entry, into the newborn's chart; (2) bar coding; and (3) double-signature systems similar to those used by blood banks.[38]

A policy and procedure must be in place should an error occur in which a newborn is fed the wrong breast milk. State laws and hospital policies regarding consent procedures for testing are to be followed. It is imperative that the confidentiality of the donor mother be maintained. The policy and procedure must ensure that the recommendations for management of inadvertent administration of breast milk (not obtained from the infant's mother) and accidental exposure are provided by the CDC and include guidance for the provider to:[37]

Inform the mother who expressed the breast milk of the bottle switch, and ask:

- When the breast milk was expressed and how it was handled prior to being delivered to the caretaker or facility
- Whether she has ever had an HIV test and, if so, would she be willing to share the results with the parents of the child given the incorrect milk
- If she does not know whether she has ever been tested for HIV, would she be willing to contact her physician and find out if she has been tested
- If she has never been tested for HIV, would she be willing to have one and share the results with the parents of the other child

Discuss the mistaken milk with the parents of the child who was given the wrong bottle:

- Inform them that their child was given another child's bottle of expressed breast milk

- Inform them that the risk of transmission of HIV is very small
- Encourage the parents to notify the child's physician of the exposure
- Provide the family with information on when the milk was expressed and how the milk was handled prior to its being delivered to the caretaker so that the parents may inform their own physician
- Inform the parents that their child should soon undergo a baseline test for HIV

The risk of HIV transmission from expressed breast milk consumed by another child is believed to be low because, in the United States, women who are known to be HIV positive and made aware of that fact are advised NOT to breastfeed their infants. Chemicals present in breast milk act, together with time and cold temperatures, to destroy the HIV present in expressed breast milk and transmission of HIV from single breast milk exposure has never been documented.

NEWBORN FEED PREPARATION

Newborn feeds, formula, or expressed breast milk are to be prepared using aseptic technique. They are not to be prepared at the bedside.[36] Care must be taken with every step of the preparation to prevent the introduction of microbial contamination and feed labeling and delivery errors. Additional information concerning infant feeding can be found in **41. Neonates**.

Postpartum (Post Discharge) Infections and Surveillance for Healthcare-associated Infections in Women and Newborns

Targeted surveillance that includes post discharge information should be done to establish HAI infection rates.[27] HAIs that occur in the woman include endometritis, UTIs, surgical site infections (SSIs), bloodstream infection, episiotomy infection, and breast abscesses or mastitis (Table 43-4).[39] Newborns may acquire HAIs, bloodstream infection, circumcision site infection, omphalitis, skin infection, and eye infection.

Table 43-4. Cesarean Section Surgical Site Infection Rates With Risk Index Categories (2006 to 2008)[40]

Table 43-4 Cesarean Section Surgical Site Infection Rates With Risk Index Categories (2006 to 2008)

Operative Procedure	Duration Cut Point	Risk Index	*n*	Rate
C-Section	56	0	20,743	1.46
	56	1	8,995	2.43
	56	2,3	1,256	3.82

The National Healthcare Safety Network (NHSN)[39,40] provides HAI rates and definitions that can be used as a benchmark for cesarean delivery infection surveillance. For cesarean section surveillance, variables on labor, blood loss, and body mass index can be collected and entered into NHSN. The NHSN surveillance methodology for cesarean section SSI based on risk index is outlined in **37. Surgical Site Infection**.

As mentioned previously, because the postpartum hospital stay for most women is short, post discharge surveillance is essential to detect and treat infections. A study on post discharge surveillance through questionnaires to the physician found that with only inpatient surveillance, 59 percent of cesarean delivery infections would have been missed. Hulton et al.[41] and Yokoe et al.[42] found, when they reviewed automated ambulatory medical records, hospital and emergency room claims, and pharmacy codes of 2,826 health maintenance organization members who gave birth over a 30-month period, that 94 percent of postpartum infections manifested after hospital discharge. This study reported that 74 percent of the post discharge infections were diagnosed and treated entirely at ambulatory centers, without the patient returning to the hospital where she delivered for evaluation and treatment. The study listed postpartum infection rates by anatomical site and by delivery method (vaginal or cesarean) (Table 43-5). The patients were followed for 30 days after delivery. The overall postpartum infection rate was 6 percent. Mastitis and UTIs accounted for more than 80 percent of the infections. The study reinforces the need for post discharge surveillance.[42]

Table 43-5 Thirty-day Postpartum Infection Rates (Jan. 1993-June 1995)

Rates of Infection					
Type of Delivery	Overall	Endometritis	Urinary Tract Infection	SSI * Episiotomy Site infection**	Mastitis
C-section	7.4%	0.8% (0.2%, 1.9%)	1.1% (0.4%, 2.5%)	3.4% (2.0%, 5.4%)	1.7% (0.8 3.2%)
Vaginal	5.5%	0.2% (0.1%, 0.5%)	2.0% (1.4%, 2.6%)	0.3% (0.2%, 1.9%)	3.0% (2.4 3.8%)

*Surgical site infections: C-section delivery
**Episiotomy site infections: Vaginal delivery
From Yokoe DS, Christiansen CL, Johnson, R. et al. Epidemiology of and surveillance for postpartum infections. *Emerg Infect Dis*2001;7:837–841; means and first and third quartiles shown.

To capture an accurate number of HAIs, the infection prevention and control professional will need to determine which databases are available to assist in capturing the post discharge infections. The use of data from health maintenance organizations or other specific surveillance programs may be helpful.

PUERPERAL ENDOMETRITIS

Endometritis occurs in 1 to 3 percent of vaginal deliveries and 10 to 50 percent of cesarean section deliveries. Endometritis is characterized by the presence of a fever (temperature higher than 38°C, or 100.4°F), uterine tenderness, abdominal pain, foul-smelling lochia, or tachycardia.[6] Of these, fever is most characteristic and may be the only sign early in the course of infection.

The CDC considers endometritis an HAI unless the amniotic fluid was infected at the time of admission or the patient was admitted more than 2 days after rupture of membrane (day 1 = rupture day). Endometritis must meet at least one of the following criteria:[39]

1. The patient has organisms cultured from fluid (including amniotic fluid) or tissue from the endometrium obtained during an invasive procedure or biopsy.
2. Patient has at least two of the following signs or symptoms: fever (> 38°C), abdominal pain,* uterine tenderness,* or purulent drainage from uterus* (*with no other recognized cause).

Mechanisms of infection include ascending infection during labor, prolonged or premature ROM, vaginal examinations, incomplete removal of placenta, and virulence and number of bacteria colonizing the lower genital tract (e.g., bacterial vaginosis). Factors that increase the risk for the development of endometritis include cesarean delivery, prolonged ROM, prolonged labor with multiple vaginal examinations, intrapartum fever, and lower socioeconomic status.[6]

Organisms responsible for causing endometritis are usually endogenous (mother's own flora) from the lower genital and gastrointestinal tract. However, infections with GAS or *S. aureus*may be either endogenous or exogenous. Endometritis is often polymicrobial caused by both skin and vaginal flora and organisms.

Diagnostically, a blood culture may be indicated if septicemia is suspected. Cervical, vaginal, or endometrial cultures do not need to be routinely performed.

Treatment is usually combined antimicrobial therapy until the patient is afebrile. If fever persists beyond antibiotic treatment for 24 to 48 hours, alternative etiologies should be considered.[6]

Cases of puerperal endometritis caused by β-hemolytic GAS, also known as puerperal sepsis or childbed fever, have declined considerably with improved attention to infection prevention but outbreaks continue to be reported. The source of the GAS is often exogenous (asymptomatic healthcare provider or other patient who is a GAS carrier). GAS is highly transmissible; even one case requires assessment and two cases should prompt a full investigation.[43]

EPISIOTOMY INFECTIONS

Infection of the episiotomy is usually mild. Episiotomy is not an NHSN operative procedure and should not be reported as an SSI but as a reproductive tract infection–episiotomy.

Episiotomy infections must meet at least one of the following criteria: (1) post vaginal delivery patient has purulent drainage from the episiotomy, (2) post vaginal delivery patient has an episiotomy abscess.[39]

BREAST ABSCESSES OR MASTITIS

Postpartum mastitis occurs in as many as one-third of breastfeeding women in the United States and leads to breast abscesses in up to 10 percent of cases. Mastitis presents with focal tenderness, swelling, warmth, and redness in the breast, sometimes accompanied by fever. If not treated appropriately, mastitis may result in an abscess, which may require surgical drainage and antibiotic treatment. In such a case, cessation of breastfeeding may occur on the affected breast but can continue on the unaffected breast. *S. aureus*is the most commonly isolated organism from breast abscesses and community-associated MRSA is an increasingly common pathogen in mastitis and breast abscesses. Antibiotics that are effective against this organism may be required.[44]

Breast abscess or mastitis must meet one of the following NHSN criteria:[39]

1. Patient has a positive culture of affected breast tissue or fluid obtained by invasive procedure.
2. Patient has a breast abscess or other evidence of infection seen during an invasive procedure or histopathologic examination.
3. Patient has fever (>38°C, or 100.4°F) and local inflammation of the breast *and* physician diagnosis of breast abscess.

Occupational Health

Consistent use of Standard Precautions by healthcare providers is imperative. The healthcare provider must assess risks, organize the care procedures to prevent exposures, and proactively use personal protective equipment to prevent unexpected exposures. Cutting of the umbilical cord can be a potential source of blood exposures to any person at the delivery. The process should be organized so that everyone is protected during the cord cutting. Those in the immediate vicinity of the procedure should consider face and eye protection and/or work practice controls such as covering the cord with a cloth. Healthcare providers must also verify that the method of suctioning used for the newborn has no risk for exposure to the healthcare provider.

To provide a healthy environment for the woman, the newborn, the family, and healthcare providers, everyone who works in a perinatal area must be free of acute communicable diseases; know their immune status (e.g., rubella, varicella, HBV, VZV); be screened for tuberculosis based on the annual risk assessment; and have appropriate immunization as per local and state occupational health and safety policies and guidelines.[45,46]

Healthcare personnel with infectious respiratory conditions (e.g., influenza, colds), gastroenteritis, dermatitis on hands, herpetic whitlow, varicella, shingles, conjunctivitis, or rashes should not work with these conditions until they have received clearance through the occupational health department, because there is a high risk for infecting the woman, newborn, and family.[45]

Conclusions

The woman and newborn must always be considered as one when managing their care because the health and interventions of the woman will affect the outcome of the newborn. Host factors and interventions must both be managed carefully. Management of the pregnant woman and her newborn can vary, from supporting a healthy woman and newborn in a home birth or birthing center to the management of a high-risk woman in an operative setting and the possibility of managing a newborn in a neonatal intensive care unit. The healthcare team must aim to decrease HAIs through the use of evidence-based practice guidelines, while providing for supportive, family-centered care. New interventions are being developed to improve the outcomes of women and newborns. Vigilance is necessary to verify that standards and policies are being followed. Precise and timely communications between the obstetrical team, the pediatric team, and the family is imperative so that the necessary interventions can be taken when indicated.

Supplemental Resources

American Academy of Pediatrics, American College of Obstetricians and Gynecologists: *Guidelines for Perinatal Care*, 7th ed. Elk Grove Village, IL: American Academy of Pediatrics, Washington, DC,

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Infection Prevention in Oncology and other Immunocompromised Patients

Author(s): Kim M. Boynton-Delahanty, BSN, MBA/HCM, CIC
Director, Infection Prevention and Control and Epidemiology

UCSD Healthcare
San Diego, CA

Kimberly M. Hinckley, RN, BSN, CIC
Senior Infection Control Coordinator

Roswell Park Cancer Institute
Buffalo, NY

Cheryl Perego, MPH, MT(ASCP), CIC
Supervisor, Infection Control

University of Texas
MD Anderson Cancer Center
Houston, TX

Published: October 3, 2014

Abstract

Oncology patients and other immunocompromised populations are at increased risk for acquiring healthcare-associated infections because of their underlying disease processes and/or treatment regimens that result in neutropenia and impaired immune response. Treatment of infection is often more difficult in this population; therefore, prevention is key. Enhanced infection prevention measures that focus on universal strategies, such as hand hygiene, barrier precautions, and environmental controls, are essential. In concert with these basics, a comprehensive infection prevention and control program must also provide the road map for identification and management of infection risks. Such risks involve exposure to communicable diseases, invasive devices, and environmental pathogens associated with air, water, and other environmental sources.

Key Concepts

- Immunocompromised patients—including those with cancer or acquired immune deficiency syndrome and those undergoing transplantation—are at greater risk for healthcare-associated infections than are other patient populations.
- Activities and environments that may be considered safe for other patient populations may pose significant risk to this population. Additional infection prevention measures may be necessary to protect these patients.
- Prevention measures should be evidence-based and current with consideration for new processes as well as new and more intense treatment regimens.

Background

Preventing infection in oncology and other immunocompromised patients is one of the greatest challenges for infection preventionists (IPs). Severe compromise of the immune system occurs as a result of intense treatment regimens and underlying disease processes. When coupled with the use of invasive devices and procedures, the risk of both healthcare-associated infections (HAIs) and community-associated infections increases and can result in higher morbidity and mortality. Infections may be caused by the patient's endogenous flora or by pathogenic exogenous organisms. Additionally, prolonged or repeated hospitalizations and treatment plans can alter a patient's endogenous flora, making him or her more susceptible to ubiquitous environmental organisms that can lead to host infection. Standard definitions for HAIs related to the latter two sources are just beginning to be defined for this population. A timely example is the recently implemented mucosal barrier injury-associated bloodstream infection as defined by the National Healthcare Safety Network.[1] This definition identifies

culture-positive bloodstream infections (BSIs) associated with mucosal barrier injuries that are not influenced by infection prevention measures (versus central line-associated BSIs that are likely preventable). IPs must also consider the fact that exposure to environmental organisms and routine activities considered safe for patients with intact immune systems may present hazards for these populations. Therefore, the interventions of experienced IPs are essential to reduce the risk of potentially life-threatening infections.

Basic Principles

- Programs to prevent infections in oncology and other immunocompromised patients must be considered in the healthcare facility's risk assessment. It should be multifaceted and interdisciplinary, involving patients, families, and healthcare personnel (HCP).
- Interventions should be based on evidence. When studies are not available, an experienced infection prevention team, utilizing focused risk assessments, is essential for developing programs to prevent HAIs.
- Feedback to stakeholders regarding the effectiveness of infection prevention interventions is critical.

Infection Prevention Measures For Immunocompromised Populations

INITIAL ASSESSMENT AND PLAN OF CARE

Compiling a comprehensive baseline assessment of the immunocompromised patient's health history prior to treatment is a crucial step in identifying the patient's risk for infection. The exam should include the patient's medical history, infection history (such as chicken pox, Epstein-Barr virus, etc.), occupation, hobbies, pets, exposure to communicable diseases, diet, nutrition, and oral health. A thorough physical examination must be performed as well to include mouth, skin, scalp, and nail beds. Additionally, documentation should be made of prescription and over-the-counter medication history, alcohol and illicit drug use, and travel and home history. Prior to therapy that may compromise the patient's immune system further (including administration of chemotherapeutic agents), identified risks should be addressed and minimized if possible. The information will also assist caregivers in developing a plan of care to reduce risk and identify potential causes of infection(s) if they develop during or following treatment.

INFECTION PREVENTION PROGRAM RISK ASSESSMENT

Annually, infection prevention and control programs should be fully evaluated for infection risk based on the population served and the care and treatments offered. Oncology and other immunocompromised patients are more susceptible to infections due to chemotherapy, radiation therapy, surgery, radiology-assisted invasive procedures, etc. As treatments of immunocompromised patients continue to expand and change, it is the IP's responsibility to keep abreast of new treatments and procedures and determine the inherent infection risks and prevention measures. In addition to risks routinely identified in acute care hospitals and outpatient clinics, infections caused by normal flora, environmental organisms, multidrug-resistant organisms (MDROs), and invasive pathogenic fungi such as *Aspergillus, Fusarium*, and Zygomycetes must be assessed for level of risk. The environment of care (including issues such as overall cleanliness, air and water quality, construction, renovation, hazard remediation, etc.) plays an important role in the safety of this patient population. The infection prevention annual risk assessment must be thorough and comprehensive. It will also need to continuously evolve due to changes in healthcare and patient population. The infection prevention team must be vigilant and responsive to change.[2]

Working with the laboratory, the IP should be aware of the laboratory's capabilities to identify the organisms causing infections in the high-risk patient population. Outside resources, such as reference laboratories, may be required to ensure that the appropriate information is made available. The IP team will conduct surveillance on these lab results and report HAI data to the infection prevention and control committee, institutional leadership, and clinicians and/or patient care units involved.

RISK FACTORS – PATIENT-RELATED

Immunocompromised Hosts: Immunosuppression occurs when an individual has one or more defects in his or her natural immune response to fight infections. This impairment can predispose the individual to opportunistic infections or life-threatening situations. For more detailed information regarding immunocompromised hosts and contributing factors, refer to **23. The Immunocompromised Host**.

Two types of immunocompromised hosts distinctly different from oncology patients are those receiving a solid organ transplantation and those receiving a hematologic malignancy transplantation. Solid organ transplantation (SOT) is an intervention used to address solid organ failure. Hematologic malignancy transplantation is a regimen used to mitigate an otherwise fatal disease process. In the past both were considered to be desperate measures. However, advances in science have now made them more widely used therapies for a variety of diseases.

SOT patients are at risk for HAIs and opportunistic and community-associated infections. The infection risk is related to the type of transplant, the state of immunosuppression needed, and the time elapsed after transplant. A thorough preoperative assessment is needed to determine the infection risk. Extensive review of this patient population and its risk factors can be found in **45. Solid Organ Transplantation**.

Hematologic malignancy transplant patients pose a more complex risk for acquiring infections. The eradication of the body's defense mechanism renders this population vulnerable to opportunistic infections. There are a variety of reasons that this patient population is at higher risk of infection. These include mucositis, neutropenia, and long-term use of invasive devices such as central lines. Standard Precautions, hand hygiene, and Transmission-Based Precautions are still the key to preventing HAIs for both populations (see **46. Hematopoietic Stem Cell Transplantation**).

Treatment-associated Risk: Varying treatment regimens in SOT and hematologic malignancy transplantation create different challenges. In SOT, a decline in living donors has been noted, thus limiting the choice for life-saving transplants. As a result, an active or latent infection may already be present in the donor, resulting in microbial invasion to the recipient. The recipient may also have latent infection brewing at the time of transplant, creating the need for prophylaxis prior to transplantation. Proper screening and history prior to transplantation are essential to decreasing the likelihood of any potential infectious process occurring.

The use of hematopoietic stem cell transplantation (HSCT) for hematologic malignancies carries the most profound risk. The preparative regimen renders the body's immune system defenseless against opportunistic infections. This is a challenge even before transplantation occurs.

Both groups of transplantations may also require other treatments that affect the transplant recipient's immune system, including chemotherapy, radiation therapy, steroid usage, and antibiotic prophylaxis. Careful monitoring of any signs and symptoms of infection are key to preventing life-threatening situations. Please refer to **45. Solid Organ Transplantation**, and **46. Hematopoietic Stem Cell Transplantation** for further details.

Apheresis regimens and other infusion treatments introduce other potential risks for infection. Long-term indwelling catheters create a vehicle for microbial intrusion and likely increase duration of stay in inpatient settings or require more frequent visits to outpatient centers. Each healthcare encounter or increased length of stay can lead to an increased risk for infection.

Surgical interventions and invasive procedures such as biopsies or endoscopic procedures challenge an already taxed immune system and allow for an additional portal of entry for microorganisms to attack.

Device-associated risk factors are of concern in the immunocompromised patient population. In most cases, the insertion of these devices is inevitable and necessary to treat, diagnose, and care for a patient. Below is a list of high-risk devices associated with potential complications in the immunocompromised host.

Central venous catheters are often necessary to safely deliver treatments to SOT, HSCT, and oncology patients. Immunocompetent patients have a lower risk for HAIs with these invasive devices than immunocompromised patients. The risks associated with these long-term catheters/ports include improper insertion and/or maintenance of the catheter and improper access practices that may potentially inoculate the patient with his or her own flora or with that of the HCP, causing central line-associated bloodstream infection or sepsis. There is literature to suggest that dedicated vascular access teams that not only place peripherally inserted central catheters but also perform the maintenance on all

central lines have a lower incidence of central line-associated complications like infections, clotting, etc. (see **34. Intravascular Device Infection**).

Urinary devices, whether indwelling or intermittent, also pose similar complications. With poor insertion and maintenance practices, the risk for introducing patient or HCP flora into the urinary tract is increased, thus increasing the risk for a urinary tract infection. This may increase the risk for introduction into the bloodstream, potentially causing a secondary bloodstream infection associated with the urinary device (see **33. Urinary Tract Infection** [UTI]).

Ventilator-associated pneumonias are also problematic for immunocompromised patients. The use of any long-term invasive device increases the risk of infection exponentially. Removal of all invasive devices once they are no longer necessary to sustain the health of the patient is one of the best ways to decrease HAIs in this population (see **36. Pneumonia**).

Environmental Risks: Endoscopes/instruments/equipment- Strict attention to proper high-level disinfection and sterilization of endoscopes and sterile equipment will prevent adverse outcomes, including infection, from occurring in any patient—not just the immunocompromised population. Ensure that appropriate equipment, disinfecting agents, and competency-verified staff completes these processes (see **31. Cleaning, Disinfection, and Sterilization**).

RISK FACTORS – HEALTHCARE PERSONNEL

It should be stressed once again that hand hygiene is the single most effective measure in reducing HAIs in hospitalized patients. HCP should commit to a conscientious program of hand hygiene with antiseptic soap formulations of proven effectiveness and alcohol-based hand sanitizers. Additionally, adherence to infection prevention practices for invasive devices is critical to prevent HAIs in the immunocompromised population. All categories of caregivers should be held to the same high standard.

Screening policies applied to visitors of immunocompromised patients should also apply to HCP who work with this population. If communicable diseases are present, HCP should be restricted from patient care duties. Daily screening or self-screening of assigned caregivers and physicians should be implemented and requires constant education and monitoring to enforce. Vaccinating HCP for influenza should be strongly encouraged and has been demonstrated to reduce influenza-like illness and mortality in a fragile population (see also **100. Occupational Health**).[3]

Immunizations: Facilities caring for immunocompromised patients should provide a robust employee health program to include a culture of safety. This culture should include a mandatory influenza vaccination policy (or staff must wear mask for patient contact). Additionally, the program should require all HCP to have all the immunizations required to meet the U. S. Occupational Safety and Health Administration's Aerosol Transmissible Diseases Standards and Tuberculosis Control Plan. An ill-worker policy should be in place and enforced. HCP should not come to work if they have any communicable or potentially communicable diseases. These include the following:

- Skin infections such as open visible wounds on the hands and forearms that are not coverable. This includes herpetic whitlow.
- Conjunctivitis
- Gastrointestinal illnesses (active diarrhea)
- Varicella infections

- Respiratory illnesses: influenza, respiratory syncytial virus, parainfluenza, or any other respiratory viral syndrome causing fever and uncontrolled secretions

These HCP should be excluded from duty for the duration of illness or infectiousness. The HCP may be evaluated and cleared by employee health (or designee) before returning to work. Refer to Centers for Disease Control and Prevention (CDC) guidelines[4] and your local employee health policies and procedures.

RISK FACTORS – VISITORS

Support from family members and other visitors is critical for the emotional well-being of the patient, but open visitation policies increase the risk of introducing communicable diseases from the community into the healthcare population. Screening programs are essential, especially during "seasons" for certain illnesses (e.g., influenza or respiratory syncytial virus). Units housing immunocompromised patients should have well-developed and strongly enforced policies to screen all visitors for symptoms of communicable illness, including diarrhea, vomiting, fever, conjunctivitis, undiagnosed rashes, and upper respiratory symptoms.[5] If symptoms are present or recent exposures have occurred, visitors should not be permitted to enter the unit. This policy may become very problematic if the symptomatic visitor is also the patient's primary support person. Decisions may have to be made on a case-by-case basis, taking the patient's medical status and emotional needs into account, as well as the visitor's ability to appropriately implement isolation techniques to adequately protect the patient.

The process for screening pediatric visitors, if they are permitted by the facility, should be more detailed and include information on vaccination status and potential exposures to communicable illnesses such as chicken pox. IPs should be aware that varicella vaccination may not be completely protective and that outbreaks of varicella with transmission among vaccinated individuals have been reported.[6]

It is also important to encourage family and other close contacts to receive an annual inactivated seasonal influenza vaccination. Live attenuated seasonal influenza vaccines are contraindicated for close contacts of severely immunocompromised persons.[7] Caregivers and family should consult their healthcare provider before receiving any live vaccinations. For example, oral polio vaccine should not be administered to household contacts of a severely immunocompromised individual, but a measles/mumps/rubella vaccine is not contraindicated. If a polio vaccination is indicated for a close contact, then inactivated polio vaccine should be administered. The degree to which a person is immunocompromised should be determined by a qualified healthcare provider.[8]

RISK FACTORS – ENVIRONMENT OF CARE

Ensuring a Clean Environment. There are a number of generally accepted guidelines for promoting a clean environment.[9,10] Cleaning and decontaminating units for immunocompromised patients should focus on removing organisms that survive in the environment and on preventing dust dispersal. Written environmental services policies should be in place, and cleaning should be performed by trained, reliable personnel. Dust accumulation should be prevented with daily cleaning of frequently touched horizontal surfaces. Cleaning methods that generate dust, such as dry dusting and mopping, should be avoided. Damp dusting and mopping using hospital-grade disinfectants is recommended for surface cleaning. High-efficiency particulate air (HEPA) vacuums should be used in carpeted areas. Doors to patient rooms should remain closed while vacuuming takes place, and patients should remain in their rooms.[11] Patient rooms cluttered with many personal belongings are difficult to clean because surfaces

are not easily accessible to environmental services personnel. In addition, belongings themselves gather dust and organisms and, depending on their construction, can be difficult or impossible to clean. Families should be encouraged to reduce the clutter that can accumulate over the long admissions sometimes required for cancer treatment and bone marrow or SOT.

Environmental cleaning also plays a vital role in preventing transmission of *Clostridium difficile*spores within healthcare settings. Primary risk factors for acquiring this organism include exposure to antibiotics, long stays in healthcare settings, and serious underlying diseases, all of which typically apply to the immunocompromised host.[12]The environment around the infected or colonized patient frequently becomes contaminated with the organism, which sporulates when conditions outside the body no longer support continued growth. Contact with contaminated patient care items and high-touch surfaces has been implicated in disease transmission, as spores can survive for extended periods on environmental surfaces. Current recommendations for environmental infection control of *C. difficile*include thorough cleaning followed by disinfection with a hypochlorite-based germicide.[10]

Newly developed assessment tools and administrative interventions can be used to improve environmental cleaning and disinfection. Carling et al demonstrated a significant improvement in thoroughness of terminal room disinfection (48 percent of standardized environmental surfaces cleaned at baseline versus 77 percent cleaned after interventions) using a surface targeting method followed by procedural interventions and repeated performance feedback to environmental services personnel.[13] Such methods would be of significant value on units housing immunocompromised populations.

Newer, novel technologies are evolving for environmental cleaning and disinfection. However, more evidence is needed to determine if these technologies aid in the reduction of HAI transmission (see also **107. Environmental Services**).

Facilities that are considering renovation of existing spaces to accommodate immunocompromised patients have the opportunity to design the environment with infection prevention in mind (see).

Linen. Requirements for linen handling and management for the immunocompromised patient do not vary appreciably from those for standard hospital populations (see **111. Healthcare Textile Services**). Although soiled linen can certainly contain large numbers of organisms capable of causing infection,[14] transmission to patients appears to be rare. Studies suggesting linen as a source of infection have failed to confirm it as the actual source, as the causative organisms were also found on patient care items and HCP hands.[10]Furthermore, given that linen washed and dried per standard hospital protocol contains very few pathogenic organisms when processing is complete,[9]it is unnecessary to provide sterile linen for immunocompromised populations. The mechanical actions of washing and rinsing, combined with hot water and/or the addition of chemicals such as chlorine bleach, and a final commercial dryer and/or ironing step, significantly reduce bacterial counts.[15]

Plants and Flowers. Flowers and plants are known to harbor microorganisms, many of them potentially pathogenic to immunocompromised patients, though there is a lack of data conclusively linking the presence of these organisms to increased incidence of HAI. Vase water from fresh flowers has yielded, among other known pathogens, Gram-negative bacilli such as *Pseudomonas aeruginosa.*Dried and fresh flowers and potted plants can harbor fungi such as *Aspergillus*and *Fusarium*spp.[10]Therefore, it is prudent to exclude plants and flowers, both fresh and dried, from units housing severely immunocompromised patients.[11]

Food and Drinking Water. Because of conditioning regimens or other immunosuppressive therapy, patients undergoing chemotherapy, HSCT, or SOT may be at increased risk of foodborne illness. Mucositis from radiation or chemotherapy; antimicrobial therapy; decreased stomach acidity resulting from treatment with H2 blockers; impaired intestinal motility; and impaired humoral or cellular immunity can all predispose to infection caused by ingested microorganisms, with small inocula capable of causing systemic disease in these populations.[16] The CDC recommends a low microbial diet for 3 months after autologous HSCT transplant and until all immunosuppressive drugs are discontinued for allogeneic recipients.[11] Low microbial diets have focused on restricting raw fruits and vegetables because of concerns about contamination with Gram-negative bacilli.[16]

Anorexia, mucositis, nausea, and food likes and dislikes may make it difficult to maintain nutrition in the immunocompromised patient. If family members prepare food at home to stimulate the appetites of hospitalized patients, all guidelines for safe food preparation must be followed, including scrupulous hand hygiene before handling food, using clean utensils and food-preparation surfaces, cooking to temperatures recommended by the U.S. Department of Agriculture (poultry to 180°F, meat and egg-containing casseroles to 160°F), and reheating foods to 165°F and soups to a rolling boil before serving.[11] And though patients with poor appetites are likely to be tempted by food from their favorite restaurant or from those prepared by other families or support groups, food preparation techniques in off-site locations cannot be monitored closely, and organisms causing gastroenteritis and Hepatitis A are more likely to be introduced through this setting than through the hospital kitchen.[17]

Additionally, tracking food recalls is difficult if the products were not distributed by the healthcare facility's food services department. Therefore, restaurant food, and that prepared by other families or groups, should not be brought into the hospital for immunocompromised patients.

The diets of medically fragile patients are frequently supplemented with enteral feedings. These solutions have the potential to become contaminated by bacteria capable of causing severe infection, and it has been suggested that an association exists between gastrointestinal colonization with organisms found in enteral feedings and healthcare-associated pneumonia. Organisms cultured from enteral feedings have included *Staphylococcus epidermidis, Staphylococcus aureus,* and Gram-negative bacilli such as *Serratia, Klebsiella, Enterobacter*, and *Pseudomonas* spp. Manipulation of the enteral feeding products and systems during preparation and administration can be the cause of such contamination, as can the use of nonsterile powdered formula preparations,[18] and mixing enteral feeds on-site results in more highly contaminated solutions compared with premixed feeds. In addition, colony counts in enteral feedings increase with the hang time of the product and the administration set.[19]

Although more research is required to determine the clinical consequences of enteral feed contamination, it is reasonable to recommend that high-risk patients receive ready-to-feed enteral feeding via closed systems and that administration sets should be changed every 24 hours.

Water Systems. The water supply for healthcare institutions reflects the community supply and may consist of underground or surface water. Consequently, water quality for particular institutions can pose different risks for acquisition of infectious disease depending on local testing, treatment, and watershed protection. Infection prevention decisions about interventions for testing and treatment of hospital water must depend on the water supply, susceptibility of patients, and historical outbreak information (see in HCF).

Although daily bathing is recommended for immunocompromised patients such as those receiving bone marrow transplants,[11] showers have been controversial. Several studies have suggested an association between aerosols from showerheads and aerators and outbreaks of *Legionella, Acinetobacter*, and even *Aspergillus* spp., but further data are needed before a recommendation to prohibit showers in this population can be made. In the meantime, IPs should be aware of water quality issues in their facilities and communities at large and make decisions regarding bathing based on this knowledge. If clusters of infections occur and an association with showerheads or aerators is suspected, a program of regular cleaning and decontamination of the equipment or complete removal may be warranted.[10]

Legionella. Since the discovery of the organism now known as *Legionella* in 1976, 42 species have been identified. It is now known that infections caused by this organism predated the 1976 outbreak at the American Legion Convention in Philadelphia. This nutritionally fastidious Gram-negative saprophytic bacterium survives in aquatic environments and moist soil and is ordinarily transmitted to humans through inhalation or aspiration of contaminated water (see **84. Legionella pneumophila**). Heightened awareness of healthcare-associated *Legionella pneumophila* among physicians treating immunocompromised patients is necessary, as diagnosis of *L. pneumophila* requires special laboratory testing, and treatment requires specific antibiotics.[20,21]

Several states have specific public health department guidelines for the prevention, detection, and control of Legionnaires' disease with specific recommendations for facilities that care for HSCT and SOT recipients. Two such states include New York[22] and California.[23]

Animals. Experts in rehabilitation medicine advocate animal-assisted therapy to enhance physical, cognitive, and emotional participation in treatments. Ordinarily, dogs are selected for this role and, in order to minimize risks to patients, undergo health monitoring by veterinarians and training to encourage docile behavior. Animals involved in pet therapy visit patients as appropriate depending on individual needs, but involvement of immunocompromised patients in pet therapy programs should be carefully considered, because even visits by healthy animals may pose risks for medically fragile patients. Healthy dogs, for example, can shed *Capnocytophaga canimorsus*, part of their normal oral flora, or *Leptospira* spp., both potential pathogens in immunocompromised patients. Animals that pose an unacceptable risk of zoonotic disease because of an inability to control secretions or the risk of a particularly concerning organism include puppies, kittens, mice, rats, skunks, raccoons, bats, reptiles, and amphibians.[17] These animals should not be part of a pet therapy program.

Service animals providing assistance to individuals with disabilities are becoming more common in our society and by law must be allowed in public places, including healthcare facilities (see **122. Animals Visiting in Healthcare Facilities**). A service animal may be one of several species, but most often is a specially trained dog. Given that service animals cannot be denied accommodation, infection prevention principles must be applied for protection of patients, employees, and visitors. On units housing immunocompromised patients, a private room should be dedicated to the disabled person and service animal, and staff members should have no direct contact with the animal nor be responsible for its care. Arrangements for defecation and urination by the animal need to identify the person responsible if the patient is not capable of attending to these tasks, areas on the hospital grounds that are acceptable for this purpose, and disinfection procedures for accidents. Areas from which the service animal is restricted within the facility need to be clearly delineated. Bites or scratches caused by the animal must be reported immediately to facilitate corrective action. The need or advisability of a patient maintaining a service animal while undergoing complex chemotherapy or transplant has not been studied, to our knowledge. The risk of zoonoses to a medically fragile population may be significant, and the acuity of

illness during hospitalization may result in staffing levels that preclude the need for a service animal. The importance of a service animal to the recovery of the patient and the risk to other severely neutropenic patients housed in the same area of the hospital have to be weighed, as do the behavior and species of the specific animal considered.

Flooding, Water Intrusion, and Mold. Molds can be found almost anywhere; they can grow on virtually any organic substance (wood, paper, carpet, foods, insulation), as long as moisture and oxygen are present. When excessive moisture accumulates, mold growth will often occur, particularly if the moisture problem remains undiscovered or unaddressed. It is impossible to eliminate all mold and mold spores in the indoor environment. However, mold growth can be controlled indoors by controlling moisture indoors.[24]

People with weakened immune systems may be more vulnerable to infections by molds. *Aspergillus fumigatus*has been known to infect the lungs of immunocompromised individuals. These individuals inhale the mold spores, which then start growing in their lungs. *Trichoderma*has also been known to infect immunocompromised children.[24]

The most effective way to manage mold in a building is to eliminate or limit the conditions that foster its establishment and growth. The underlying moisture condition supporting mold growth should be identified and eliminated.[25]

Construction. When an occupied medical center undertakes construction and renovation projects, substantial planning is required to protect patients from the associated risk of fungal infections, primarily aspergillosis (see). Containment measures necessary to protect at-risk populations include adequate barriers and negative pressure inside the construction site. The nature of the barrier required depends on the type of construction activity and type of service delivered in the area. Plastic may be used in low-risk areas such as office space, but hard wall barriers with sealed joints are needed in most areas delivering healthcare adjacent to demolition and/or removal of large numbers of ceiling tiles. To achieve negative pressure, air from the construction site must be exhausted to the outdoors directly through a sealed opening or indirectly through an exhaust duct.[26]

Remediation and containment plans are dependent on the amount of water damage, square footage, and building occupants. The Environmental Protection Agency (EPA) provides a detailed resource guide for handling such occurrences.[24]

Air. Most efforts to filter air in areas housing immunocompromised patients have focused on minimizing the airborne risk of *Aspergillus*, which infects between 2 and 40 percent of HSCT patients, depending on the diagnostic criteria used.[27]Although contaminated linen or clothing may contain *Aspergillus*spores that can become airborne with agitation, the most common source of filamentous fungal infections is thought to be through dissemination of airborne spores by the hospital ventilation system.[28]Although a seasonal variation in the incidence of *Aspergillus*infection has been noted, with increased incidence in the late summer and fall coinciding with higher spore counts in the outside air,[29]outbreaks in immunocompromised patients have also coincided with hospital construction projects.[30]In addition, manipulations of the ventilation systems and other internal transient events have been demonstrated to cause short-term increases in spore concentrations, known as "bursts."[9]The risk of *Aspergillus*is thought to be great enough to justify specialized housing for some immunocompromised patients. Some HSCT

patients, for instance, benefit from being housed in private rooms with a combination of environmental controls that include: (1) HEPA filtration of incoming air; (2) directed room air flow; (3) positive room air pressure relative to the corridor; (4) well-sealed rooms (including sealed walls, floors, hard surface ceilings, windows, electrical outlets) to prevent flow of air from the outside; and (5) ventilation to provide more than 12 air changes per hour.[10] Because an association between increased airborne spore concentration and healthcare-associated aspergillosis has been demonstrated,[31,32] multiple sources, including the CDC's *Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients,* recommend the use of HEPA filtration systems for allogeneic HSCT patients.[11] A HEPA system removes up to 99.97 percent of particles measuring 0.3 microns in diameter from the air and can effectively reduce the number of circulating *Aspergillus* spores from the patient's ambient air. Although unfiltered outside air can contain up to 15 *Aspergillus* spp. colony forming units (cfu) per cubic meter, Rhame has demonstrated that the use of HEPA filtration and increased air changes can reduce the concentration to the range of 0.01 cfu per cubic meter.[32] Portable HEPA filtration systems, though available, have been less well studied than those installed in hospital ventilation systems.[5]

Even with HEPA systems, the risk of airborne infection is not zero. Despite the fact that no consensus has been reached on the density of fungal spores at which risk of invasive *Aspergillus* infection is increased,[33] HEPA-filtered air in areas housing immunocompromised patients should be sampled for fungal spores on a schedule determined by IPs and based on perceived risk within the facility. At the least, sampling should occur after HEPA filters are changed, before opening areas in which construction has been performed to immunocompromised patients, and when investigating outbreaks of invasive *Aspergillus* infection.[5] The facility's level of fungal disease should be considered when determining frequency of air sampling. Current air sampling strategies include impactor air samplers, which allow cultures of larger volumes of air at a faster rate.[24] Newer strategies suggest that in the future less reliance may be placed on air cultures, as more experience with and data from particulate samplers is available. Because no incubation period is required with this sampling method, more rapid evaluation of air quality, assessments of safety for patients, and occupation of areas formerly under construction are possible. There are currently no widely accepted safety thresholds for either particulate or culture methods of air sampling and no commonly accepted definitions of hospital-acquired fungal infections to facilitate surveillance and timely interventions. Facilities have established their own thresholds for concern, creating difficulties in comparing data between centers. Further research in this area is needed.

Immunocompromised patients must occasionally leave their rooms and units for necessary procedures that cannot be performed at the bedside. The CDC's 2007 *Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings 2007*[34] recommends that, during periods of hospital construction, allogeneic HSCT patients wear N95 respirators when out of a protective environment (i.e., one with HEPA-filtered air and positive pressure relative to adjacent air spaces). Although fit tests are generally thought necessary for effective use of such respirators for HCP, CDC has made no recommendation regarding the necessity of fit tests for patients.[35] No commercially available respirator, however, has been tested for its efficacy in reducing exposure to *Aspergillus* spp. or its usefulness for HSCT patients.[11] Further studies are necessary to establish whether it is possible to protect immunocompromised patients from exposure to mold spores by having them wear currently available respirators.

Waiting/Reception Areas. Respiratory hygiene/cough etiquette is a very important aspect of Standard Precautions. Triage, reception, and waiting areas often provide an initial point of contact in healthcare facilities. Therefore, respiratory hygiene/cough etiquette strategies are key in these areas. The program should not focus on just patients but should include those accompanying the patient.[36]

In addition, prompt patient screening for potentially symptomatic and asymptomatic infectious individuals is necessary to reduce the opportunity for infection transmission. This is especially important for airborne infections. Transmission of vancomycin-resistant enterococcus (VRE) and methicillin-resistant *Staphylococcus aureus*(MRSA) in the outpatient setting has not been reported.[34]

IPs should be involved in the selection of furnishings and ornamental features, such as water features, to evaluate how they will be cleaned and any potential infection risks (see also).

SEQUELLAE

Oncology and immunocompromised patients are more likely to have longer hospital stays during and following treatment because of their continued need for invasive devices; acquisition of infections due to MDROs; reactivation of varicella zoster; development of mucositis, diarrhea, and/or sepsis caused by the translocation of intestinal flora; and acquisition of opportunistic infections. Readmissions are more likely in this population because of treatment-specific sequellae and inadequate immune response. As a result, these patients are at high risk for infection.

After discharge, the patients will likely have repeated visits to outpatient centers to receive chemotherapy, blood products, and/or infusions. Most patients will be subjected to invasive procedures while they are inpatients and/or outpatients as part of their treatment regimen or follow-up. Risk assessment and infection prevention measures should be conducted and implemented in these settings as well.

Infections caused by MDROs are a major complication in cancer patients and immunocompromised hosts. MRSA, VRE, and multidrug-resistant *Pseudomonas aeruginosa*are associated with high morbidity and mortality, particularly in oncology patients. Infections and outbreaks associated with environmental organisms are often difficult to retrieve and identify. Susceptibility testing should be performed to treat these infections successfully. CDC guidelines and professional society recommendations[34,35,36]should be closely followed and compliance monitored, to ensure that wearing of appropriate personal protective equipment and disinfection of medical devices is completed. Conscientious attention to cleaning and disinfecting the environment of care is essential.

INFECTION CONTROL SURVEILLANCE

Per the *Guidelines for Preventing Infectious Complications among Hematopoietic Cell Transplantation Recipients: A Global Perspective 2009,*[37]institutions should follow standard guidelines for surveillance of epidemiologically significant healthcare-associated pathogens (such as MRSA, VRE, multidrug-resistant Gram-negative bacilli, *C. difficile*, and invasive mold infections) and their susceptibility patterns. In the absence of epidemiologic clusters of infections, there is no need to perform routine bacterial surveillance cultures of the hematopoietic cell transplant (HCT) center environment, equipment, or devices used for respiratory therapy, pulmonary function testing, or delivery of inhalation anesthesia. Furthermore, in the absence of a healthcare-associated fungal outbreak, it is not necessary to perform routine fungal cultures of devices or dust (such as settle plates) in the rooms of HCT recipients and candidates undergoing conditioning therapy. However, HCT center personnel should perform routine surveillance for

cases of invasive mold disease, including aspergillosis, occurring among HCT recipients. The optimal surveillance definition for healthcare-associated invasive mold disease is unclear. Because HCT recipients have frequent contact with ambulatory healthcare facilities and the incubation period for invasive mold disease is unknown, all cases of invasive mold infection should be tracked regardless of time to onset after admission. Cases of invasive mold disease with onset of symptoms 7 days after hospital admission are more likely to be hospital-associated. Surveillance definitions can include definitions for proven, probable, and possible cases, and criteria can include culture, histology, host factors, indirect tests for detection of fungal antigen or cell wall constituents, and clinical (including radiology) data. An increase in the number of cases or in the incidence of invasive mold disease among HCT recipients should trigger careful evaluation of the HCT center environment for sources of mold exposure. In addition, the ventilation system should be evaluated to ensure adequate filtration, airflow, and air pressure differentials (see **114. Heating, Ventilation, and Air Conditioning**).

PREVENTION PROGRAM RESPONSIBILITIES – PATIENT AND FAMILY EDUCATION AND COMMUNICATION

Because immunocompromised patients are at higher risk for acquiring infections, it is important that they participate in education about prevention. This education should include the importance of hand hygiene, the care of invasive devices (e.g., central venous catheters, urinary devices), and caring for wounds. This is especially important for patients going home with these invasive devices. Patients should be encouraged to be their own advocate and feel empowered to ask others to perform hand hygiene before contact with them, their invasive devices, or wound dressings.

When patients are immunocompromised, they should avoid sick people and crowds, especially during seasons associated with higher respiratory infections, such as cold and influenza season.

Additionally, education should include good personal hygiene, oral care/dental hygiene, rest, eating a well-balanced diet, and never handling animal excrement. Patients should also be educated regarding the signs and symptoms of infection and to contact their healthcare provider if infection is suspected.

As mentioned, many infections in the immunocompromised population are caused by the patient's endogenous flora, especially during periods of severe neutropenia. Common sense suggests that maintaining good personal hygiene might decrease the risk of infection. Clothes worn by patients should be clean and changed regularly. Patients should take daily showers or baths using a mild soap, and daily attention should be paid to skin integrity. Inspection of the skin can be done by the patient, nursing staff, or a parent or family member, and special attention should be paid to areas of concern, such as the perineum, perianal area, and sites of intravascular access.[3] For infants, skin folds and diaper areas should be inspected for yeast and treated as required. Sterile water is not usually thought necessary for bathing immunocompromised patients unless there is a documented problem with water quality.[28] Finally, water testing based on outbreaks and a facility's historical HAI data is appropriate to document safety.

Good oral and dental hygiene are essential for immunocompromised patients. The oral cavity is a reservoir for microorganisms capable of causing life-threatening infection. The severe mucositis experienced by many oncology patients predisposes to translocation of these organisms into the bloodstream. A program of gentle oral hygiene involving rinses with sterile water, normal saline, or bicarbonate solutions and brushing with a soft toothbrush is recommended in the CDC's *Guidelines for Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients*,[11] whereas other sources suggest that brushing teeth may increase the risk of bacteremia or bleeding.[5] Based on

the severity of mucositis and level of neutropenia, instruct patients on when to brush teeth or use another method of oral hygiene.

Hand washing is the "single-most critical and effective procedure for preventing healthcare-associated infection,"[11] and patients and family members, as well as HCP, should be taught the importance of this intervention. Pediatric patients need to be instructed in the proper methods of hand hygiene and need reminders and assistance in performing this task. Parents are best situated to help the pediatric patient and often become vigilant "gatekeepers," conscientiously monitoring the hand hygiene habits of all who have contact with their child. This involvement can be valuable and should be fostered, with one study indicating a 34 percent increase in soap usage during a program in which patients were taught to ask caregivers whether they had washed their hands before delivering care.[38]

Washing with plain hand soap and water physically removes some transient microorganisms but fails to achieve the level of reduction of antiseptic products and leaves no persistent activity on the skin. Plain soap has also proved unreliable in the removal of tenacious microorganisms such as VRE[39] and may even spread some organisms such as rotavirus further over the surface of the hands.[40] For these reasons, the use of hand cleaning agents achieving maximum reductions in bacterial counts has been recommended when working with immunocompromised populations.[11] Such products include those containing chlorhexidine gluconate, iodine and iodophors, and triclosan.

Most, if not all, hospitals have incorporated the use of alcohol hand sanitizers into their hand hygiene programs. When used appropriately, alcohols provide a rapid and effective reduction in microbial counts on the skin, with one study indicating a 4-log (99 percent) reduction in microorganisms from baseline levels after application of a product containing 62 percent ethanol.[41] Using an alcohol hand sanitizer is easier and faster than hand washing, taking only about 1 minute to apply and dry, and a sink and water are unnecessary. Alcohols are not good cleaning agents, however, and are not recommended for use if physical dirt is present on the skin.[31] In addition, alcohol hand sanitizers are not sporicidal and, unlike soaps containing antiseptic agents, alcohols leave no persistent chemical effect on the skin. HCP should clean their hands with soap and water when they are visibly soiled and when working with patients with *C. difficile*-associated diarrhea, as well as when there is suspected or documented exposure to *Bacillus anthracis*-contaminated items.[42]

Recently published studies have demonstrated the potential benefit of daily patient bathing with chlorhexidine-impregnated washcloths. There was a significant reduction with respect to bacteremias and the acquisition of MDROs in critical care and bone marrow transplant populations.[43,44]

STAFF EDUCATION

To maximize infection prevention in oncology and immunocompromised populations, staff education should be provided for new employees as well as current employees, including contract workers, students, and volunteers. IPs should ensure through surveillance of activities that caregivers and care support staff are compliant with prevention measures, as well. Annual educational updates should be provided on the prevention of bloodborne pathogens and tuberculosis, care and access of invasive devices (such as central lines, indwelling urinary catheters, and ventilators), and surgical site infection prevention. Training should also be provided for universal programs such as hand hygiene and respiratory virus prevention. In settings where high-level disinfection or sterilization is performed, annual training and competency review should also be completed and documented. Additionally, ongoing

training for the appropriate use of low-level disinfectants is essential for the assurance of a safe environment. Novel educational offerings can be used that include relevant tasks for these populations, such as videos, slide sets, educational games, or small group poster sessions that focus on hand hygiene, insertion of urinary catheters and routine meatal care, accessing the central line, scrubbing the hub, catheter site dressing changes, use of barrier precautions, nasal wash collection for respiratory virus cultures, etc.

PREVENTION STRATEGIES FOR DEDICATED CANCER CENTERS, COMMUNITY HOSPITALS, AND OUTPATIENT FACILITIES (RISK STRATIFICATION)

In all settings, it is of utmost importance for the IP to spend time in the patient care environment to directly observe practices—including hand hygiene compliance, central line insertion, linen changing, and disinfecting of the environment between patients. Based on observations and risk assessment for the healthcare setting involved, the prevention strategies may be different.

Although important in all healthcare settings, the prevention of MDROs is paramount in centers that care for oncology and other immunocompromised patients. One important key to minimizing infections is a robust antimicrobial stewardship program. Together with a comprehensive hand hygiene program, an ongoing system for the identification of infected or colonized patients and subsequent routine use of appropriate use of personal protective equipment should be in place.

Conclusions

In the United States, the CDC reports that more than 1.5 million new cancer cases were diagnosed in 2010.[45]Patients with cancer and other immune disorders are living longer through research findings and improved treatment regimens. However, patients are also receiving more intense treatment regimens that often lead to profound immune compromise and HAIs. Repeated and/or longer hospitalizations may occur and increase a patient's risk of exposure and infection with pathogenic and ubiquitous organisms. Fundamental and novel infection prevention interventions are necessary to manage and protect patients with impaired immune systems. Some of these interventions are complex and costly (HEPA air filtration, water disinfection systems, etc.). Others are basic and relatively inexpensive (hand hygiene, meticulous care of central lines, screening of personnel and visitors for communicable illness). Increasing the effectiveness of infection prevention and control programs can lead to better outcomes for patients, but the challenges are many. Identifying the source of infection is also a challenge. It can be difficult to determine if it was acquired in the community, during a current or previous hospitalization, or in an outpatient setting, especially if a patient has been at multiple facilities. The new reality is that prevention activities must expand and reach across the continuum of care as more immunocompromised patients receive complex treatment in various arenas. New infection prevention products and services are rapidly becoming available to assist in reducing the risk for infection. To better identify organisms associated with infection and exposure, new sophisticated laboratory testing is becoming increasingly available for routine use. Genomic testing of a variety of microorganisms is available for use in identifying the relatedness of one organism to another to assist in cluster or outbreak investigations. As products are trialed, evidence-based literature should be reviewed along with relevance to your practice. The cost and return on investment should also be considered for each population. In summary, it is clear that multifaceted and dedicated infection prevention programs are necessary for the safety of these immunocompromised patients. By focusing on the mainstays of infection prevention (hand hygiene, respiratory etiquette, clean environment, and engaged staff) along with thorough risk assessment and

implementation of appropriate evidence-based prevention measures using novel approaches, the risk for infection will be minimized.

Through development of leadership skills, dedication, certification in infection control and prevention, ongoing training, and willingness to serve, the outlook for contributions by IPs in the oncology field is bright. By using the tools available to IPs through national and professional guidelines, evidence-based literature, networking with other seasoned IPs, and the intense drive to keep these patients safe from infectious sequellae, we can develop and provide robust infection prevention measures to minimize the infection risk in the immunocompromised population and provide the foundation for improved survival and quality of life.

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Solid Organ Transplantation

Author(s): Patricia L. Harris, MSN, RN, CIC
Nurse Manager

Department of Veterans Affairs
Veterans Affairs Pittsburgh Healthcare System
Pittsburgh, PA

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Abstract

Solid organ transplant surgical interventions are accepted therapies for end-stage organ failure. During the past decade, surgical techniques, immunosuppressive therapy, and infection prevention approaches have improved outcomes. However, infectious complications after transplant continue to be significant causes of morbidity and mortality. Infection risks vary with history of the patient, type of organ transplant, level of immunosuppression, immunosuppressive agent type, and amount of time following the transplant surgery. A review of current literature and national guidelines was conducted for this chapter, which identified infection risks to the solid organ transplant recipient as well as infection prevention measures to reduce the risks.

Key Concepts

- Solid organ transplant patients are at risk for healthcare-associated, opportunistic, and community-associated infections.
- The type of organ transplant, net state of immunosuppression (level, agent type), and time elapsed after transplant influence infection risk.
- Thorough preoperative history and assessment may predict opportunistic infection risk.
- Infection prevention practices, such as Standard Precautions, hand hygiene, and isolation practices, are key to preventing healthcare-associated infections.

Background

The transplantation of an organ from one body into another is a great accomplishment in medical science, but even greater is the ability of this organ to function without the recipient's body rejecting the allograft tissue. By 1964, approximately 30 kidney transplants from identical twin donors and the first liver transplant had been performed.[1] The first human heart transplant was performed on December 3, 1967.[2] In 1983, the introduction of cyclosporine into immunosuppressive regimens led solid organ transplantation into a new era.[1] During the past 40 years, impressive advances have been made in surgical techniques, transplant recipient care, and immunosuppressive therapy to prevent graft rejection.

Today, solid organ transplantation (SOT) is widely accepted for treatment of end-stage organ failure, and the number of transplants performed and patients living after transplant continues to increase. According to the 2011 Organ Procurement and Transplantation Network (OPTN)/Scientific Registry of Transplant Recipients (SRTR) 2011 Annual Report, 794 solid organs were transplanted during 2011 in the United States, with 1,683 of those being pediatric transplants.[3,4] As of December 2013, 121,100 persons were on the solid organ transplant waiting list.[5]

Improved immunosuppressive regimens have been associated with significant decreases in rejection, thereby enhancing both allograft and patient survival.

However, infections continue to be a major determinant in patient outcome. Factors influencing infection risk in the SOT recipient include type of organ transplanted, net state of immunosuppression (level, agent type), amount of time after transplant, latent infections in the donor or recipient, and environmental factors. Understanding the risks over time and the pathogens associated with SOT infections will assist in the development and implementation of infection prevention measures.

Although the Centers for Disease Control and Prevention (CDC) have published specific guidelines for infection prevention in patients undergoing hematopoietic stem cell transplantation (bone marrow transplant), similar guidelines are not available for patients undergoing SOT.[6] Most early infections in SOT recipients are similar to healthcare-associated infections (HAIs) experienced by any critically ill surgical patient, including device-related infections (e.g., central line-associated bloodstream infection) and surgical site infections that may be secondary to resistant organisms. Extensive guidelines have been published to prevent such infections, as have environment guidelines, and these should be applied to the SOT recipient. Specific infection prevention guidelines for SOT recipients are available in the form of texts, peer-reviewed journal articles, and other guidelines, some of which are listed as resources at the end of this chapter. This chapter provides an overview of HAIs and opportunistic infections seen in SOT recipients and infection prevention guidance to reduce infections after transplant, thereby improving SOT recipient outcomes.

Basic Principles

Due to the limited number of donor organs available, both living and deceased donors are used to increase the availability of organs. The most common living donation is kidney followed by living liver donors. The number of living liver donors has gradually decreased over the past years due to reports of two donor deaths in 2010. In addition, there have been nine living lung transplants since 2005.[7] The advantages of living donor transplantation are that surgery can be scheduled, the organ can be implanted almost immediately into the waiting recipient, and more time is available for donor screening—all of which may reduce infection.

With both deceased and living donors, the SOT recipient is at risk for HAIs or opportunistic infections. Active or latent infection may be present in the donor, resulting in the transmission of infection to the recipient during transplantation. The recipient also may have latent infection before surgery. Therefore, it is essential that the donor and recipient be thoroughly screened before surgery to enhance understanding of the recipient's infection risk after transplant and so that prophylactic or preemptive therapy may be initiated as needed.

Although outcomes have improved following SOT, 50 to 75 percent of transplant patients continue to have evidence of microbial invasion during the first year after transplant.[8] Clinical infection may affect the recipient directly or indirectly by contributing to immunosuppression, allograft injury, and, in some cases, cancer. Therefore, preventing infection through a variety of interventions ranging from donor and candidate screening to infection prevention practices to prophylactic therapy are critical in this patient population.

Evaluation and Prevention of Infection in Solid Organ Transplantation

Infectious disease screening provides the opportunity to identify active infections that may be treated, as well as those that may disqualify the donor or recipient. In addition, screening helps to define the level of infection risk to the recipient so that preventative strategies can be considered.

PRETRANSPLANT EVALUATION

Donor Screening

United Network for Organ Sharing (UNOS) policy outlines the minimum procurement standards for evaluation of potential donors (Table 45-1). Transplant centers may request additional screening of potential donors.

In some cases, Hepatitis B- and C-infected donors may be considered for transplant. The best protection against Hepatitis B is to offer Hepatitis B vaccine in the early stages of pretransplant illness. Hepatitis C virus (HCV)-positive donor organs are best used for HCV-positive recipients.[9] Both living and deceased donors should be tested for human immunodeficiency virus (HIV) and screened for HIV risk factors.[10] If the donor is high risk for HIV, he/she should be excluded from donating tissues and organs unless the risk of not performing the transplant is deemed higher than the risk of transmitting HIV. In these cases, an informed consent referencing the possibility of HIV transmission should be obtained.

Table 45-1 Donor and Recipient Pretransplant Screening for Infection Risk

Screening Test	Donor Screening	Recipient Sceening	
Minimum UNOS Requirement	Other		
Human immunodeficiency virus (HIV) antibody	X		X
Hepatitis serological testing (HBsAg, HBcAb, HCV Ab)	X		X
Venereal Disease Research Laboratory or rapid plasma reagin	X		

Anti-human T-cell lymphotropic virus I/II	X		X
Anti-cytomegalovirus	X		X
Epstein-Barr virus serological testing	X		X
Chest x-ray	X		
Blood and urine cultures in donor hospitalized > 72 hours	X	X	
Urinalysis within 24 hours of cross clamp	X		
Sputum Gram stain for lung donors	X		
Blood gases for lung and heart donors	X		
Toxoplasma antibody (especially if heart donor)		X	X
Varicella-zoster virus antibody			X
West Nile virus (nucleic acid testing of live donors)		X	
Kaposi sarcoma herpesvirus		X	
Human herpesvirus 6 and 7		X	
Herpes simplex virus IgG antibody		X	X
*Trypanosoma cruzi*serology (from endemic area)		X	
Mycobacterial infection			X
Fungal colonization (e.g., *Aspergillus,* coccidioidomycosis)			X
*Strongyloides*serology or ova and parasites if from endemic area			X
Tuberculin skin test or QuantiFERON-TB gold test		X	X

From UNOS website. Available at **http://www.unos.org**; Fishman J. Infection in solid-organ transplant recipients. *N Engl J Med*2007;357:2601–2614; Munksgaard B. Screening of donor and recipient prior to solid organ transplantation. *Am J Transplant*2004;4(Suppl 10):10–20.

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In addition to screening tests, both living and deceased donors should be screened by obtaining a thorough medical and social history. This should include a history of immunizations, previous infections, travel, occupational exposure, social histories (e.g., hunters), and any at-risk behaviors (e.g., drug use, sexual practices, and incarceration).

Pretransplant Candidate Screening

The transplant candidate should undergo similar screening: medical, social, travel, and residency history, as well as serologic testing to determine the risk for posttransplant infection (see Table 45-1). Pathogens endemic to the recipient's residence or places of travel increase the risk for infections that may not be seen commonly in the area of the transplant center (e.g., *Histoplasmosis, Strongyloides*

stercoralis). It is useful to review the infection history of the recipient because the endemic flora of hospitals in which the recipient previously has received treatment may be different from the flora of the hospital in which the transplant is to be done. Because many transplant patients may have had frequent or extended hospitalizations or outpatient treatments, such as dialysis, they may be colonized with antibiotic-resistant bacteria.

Reviewing and comparing the serological testing results of both the donor and the candidate provides a means of identifying infection risk and the need for prophylactic or preemptive therapy within the candidate or recipient. Pretransplant recipients should be assessed for active infection that may require treatment or preclude transplant. Dental, ear, nose, and throat examinations can determine the need for dental extractions or treatment and sinus infection.[11]

All transplant candidates should be screened for history of tuberculosis (TB) disease or exposure and have a tuberculin skin testing (TST) or QuantiFeron-TB Gold (QFT-G) assay done. In a recent study, TST and QFT-G were found to be comparable in diagnosing latent TB infection in liver transplant candidates.[12]Although a positive TST will provide useful clinical information, placement of an anergy panel is controversial. In one study, 50 percent of patients with positive TSTs had no response to any of the antigens used in the anergy panel.[13]Bacille Calmette-Guérin (BCG) vaccination does not preclude the need for TST.[14]

Recommendations for chemoprophylaxis after a positive TST vary.[15]However, chemoprophylaxis should be considered for candidates and recipients who have a TST ? 5 mm, patients with radiographic evidence of TB without previous prophylaxis, history of inadequate treatment of prior TB, close contact with a TB-infected person, or receipt of an allograft from a donor with a history of a reactive TST or tuberculosis without prophylaxis or treatment.[16,17]

Immunizations Among Solid Organ Transplantation Candidates and Recipients

The candidate's immunization history should be assessed before transplant, and the full complement of vaccines should be administered as early as possible before transplant to prevent posttransplant infection (Table 45-2). Theoretically, any inactivated vaccine can be administered after transplant, but immunogenic response may be limited. In 2004, The American Society of Transplantation (AST) published guidelines for vaccination of SOT recipients.[18]In 2008, an immunization update was published, which reviews the following vaccines: human papillomavirus (HPV) vaccine, varicella-zoster (shingles) vaccine, varicella vaccine, tetanus-diphtheria-pertussis (Tdap) vaccine, Hepatitis B vaccine after liver transplantation, meningococcal conjugate vaccine, pneumococcal conjugate, and rotavirus vaccine.[19]

Varicella-zoster vaccine, varicella vaccine, and other live virus vaccines are contraindicated in immunosuppressed patients.[19,20]Two recent studies have suggested that a live varicella-zoster virus vaccine may be safely administered in pediatric patients after transplant and result in an immunogenic response.[21,22]Historically, some clinicians have been reluctant to administer inactivated vaccines, including influenza vaccine, to transplant patients in the immediate postoperative period because of fear of precipitating allograft rejection. However, several small studies have documented that inactivated influenza vaccine does not affect allograft function or increase rejection.[23]In general, it is recommended that inactivated vaccines be administered at approximately 6 months after transplantation, when baseline immunosuppression levels are established, to enhance immunogenic response.[18]

Table 45-2 Donor and Recipient Pretransplant Screening for Infection Risk

Vaccine: Inactivated (I); Live Attenuated (LA)	Pediatric	Adult		
Recommended Pretransplant	Recommended Posttransplant	Recommended Pretransplant	Recommended Posttransplant	
Influenza, injectable (I)	Yes	Yes	Yes	Yes
Hepatitis B (I)	Yes	Yes	Yes	Yes
Hepatitis A (I)	Yes	Yes	Yes	Yes
Pertussis (I)	Yes	Yes	--	--
Diphtheria (I)	Yes	Yes	--	--
Tetanus (I)	Yes	Yes	Yes	Yes
Polio (I)	Yes	Yes	Yes	Yes
Haemophilus influenzae(I)	Yes	Yes	--	--
*Streptococcus pneumoniae*conjugated (I) or polysaccharide (I)*	Yes	Yes	Yes, polysaccharide (I)	Yes
*Neisseria meningitidis (I)***	Yes	Yes	Yes	Yes
Varicella (LA)	Yes	No	Yes	No
Measles (LA)	Yes	No	--	--
Rubella (LA)	Yes	No	--	--

*See cited guideline for specific pneumococcal vaccine recommendations for children.
**Recommended for specific populations; see cited guideline.
Adapted from: Munksgaard B. Guidelines for vaccination of solid organ transplant candidates and recipients. *Am J Transplant*2004;4(Suppl 10):160–163. See guideline for information pertaining to other vaccines and more detail.

*See cited guideline for specific pneumococcal vaccine recommendations for children.
**Recommended for specific populations; see cited guideline.
Adapted from: Munksgaard B. Guidelines for vaccination of solid organ transplant candidates and recipients. *Am J Transplant*2004;4(Suppl 10):160–163. See guideline for information pertaining to other vaccines and more detail.

POSTTRANSPLANT

Although critical to infection prevention, an in-depth review of the net state of immunosuppression, prophylactic and preemptive regimens, and their relationship to infection and allograft/patient outcome is

well beyond the scope of this chapter.

Risk Factors for Infection

The source of infection for the SOT recipient can be the donor organ, the recipient, healthcare-associated, or community-associated. Active or latent infection in the donor at the time of organ procurement as well as in the recipient may place the SOT patient at increased risk of infection (e.g., cytomegalovirus [CMV], toxoplasmosis). The following factors may also increase the risk of infection and adversely affect patient outcome:

1. Bacterial or fungal colonization of the respiratory tree (e.g., resistant *Pseudomonas*species, *Aspergillus*)
2. Resistant organism colonization due to frequent or prolonged exposure in healthcare systems
3. Severity of illness prior to surgery
4. Long-standing malnutrition
5. Patient age (infants have less developed immune systems and therefore may lack preexisting immunity against community-associated pathogens)
6. Disruption of physical barriers (e.g., surgery, intravascular catheters)
7. Net state of immunosuppression

Among the most important factors influencing the risk of opportunistic infections is the type and intensity of immunosuppressive regimen.[24]Calcineurin-inhibitor agents remain the mainstay for immunosuppression in transplant recipients. These agents target calcineurin not only in the human T-lymphocytes but also in fungal cells, including those of*Candida, Cryptococcus*, and *Aspergillus*. Patients receiving these calcineurin-inhibitor agents are less likely to have disseminated cryptococcosis and aspergillosis and more likely to have these infections limited to the lungs.[25,26]

The type of organ transplant is a predetermining factor for infection risk. Pneumonia is common in heart and heart-lung transplant recipients; urinary tract infection is common following renal transplant; and abdominal infection (i.e., cholangitis) is common after liver or intestinal transplantation. In addition, viral infections, such as CMV and HCV, influence the likelihood of opportunistic infections occurring, whether bacterial or fungal.[27,28,29]These infections seem to contribute to immunosuppression and weaken host defenses.[30]

With the use of prophylactic and preemptive therapy, patterns of opportunistic infections have been altered to create new patterns, which have been further altered by the emergence of new infections or infections due to resistant organisms. The time period following transplant also predicts potential infection risks.

Zero to One Month Posttransplant

During the first 30 days after SOT, incidence of HAIs are the same as those seen in any critically ill surgical patient (i.e., surgical site infection, catheter-associated bloodstream infection, pneumonia, urinary tract infection). Infections during this time are predominantly bacterial. *Candida*and *Aspergillus*fungal infections may be seen. Opportunistic infections are limited during this time period due to immunosuppressive therapy not reaching its full impact. Rarely, reactivation of latent infection is seen (i.e., herpesvirus). Human herpesvirus-6 has been identified as a pathogen seen in SOT recipients during the first month.[31]

One to Six Months Posttransplant

Infections occurring between 1 and 6 months are related to the immunosuppressive regimens given to prevent allograft rejection. If the SOT recipient requires extended hospitalization, typical HAIs continue to be a concern. Most infections during this time are opportunistic with CMV being the most common.[32]

Other opportunistic infections that may reactivate during this time period are BK virus, *Mycobacterium tuberculosis*, *Pneumocystis jirovecii*, *Toxoplasmosis gondii*, and *Nocardia*(Table 45-3).

Six Months or More Posttransplant

Community-associated infections are the most common infections 6 months or more after transplant. Varicella-zoster virus is an opportunistic infection that may reactivate during this time period as herpes zoster. However, patients with recurrent or chronic rejection, those requiring aggressive immunosuppression, and those with poorly functioning allografts (i.e., recurrent HCV in a liver transplant) continue to be at risk for opportunistic infections.[32]Reinfection with allograft hepatitis occurs in 50 to 80 percent of liver transplant recipients within 1 to 2 years after transplantation.[33]Recurrent HCV is correlated with a significantly higher incidence of opportunistic infections, recurrent episodes of infections, and late-onset infections (i.e., 6 months after transplant).[34]

With current immunosuppressive regimens, posttransplant lymphoproliferative disorder (PTLD) has emerged as an increasingly important infection that affects both graft and patient survival. Epstein-Barr virus (EBV) is the most clearly defined risk factor for PTLD, increasing the incidence by 10- to 76-fold.[35]

Because the adult population generally has greater than 90 percent immunity by age 40 years, the concern is greater among the pediatric SOT population.[36]

Table 45-3 Immunosuppressive Agents

Type	Agent
Calcineurin inhibitors	Tacrolimus (Prograf) Cyclosporine (Sandimmune, Neoral, Gengraf)
Corticosteroids	Prednisone (Deltasone) Prednisolone (Orapred)
Mammalian target of rapamycin inhibitor (mTOR)	Sirolimus (Rapamune) Everolimus (Afinitor)
Antimetabolite	Azathioprine (Imuran) Mycophenolate mofetil (Cellcept)
T-cell depleting agents	Antithymocyte globulin (ATG), Thymoglobulin OKT3 (Orthoclone, muomonab-CD3)

From Barshes NR, Goodpastor SE, Goss JA. Pharmacologic immunosuppression. *Front Biosci*<2004;9:411–420.

From Barshes NR, Goodpastor SE, Goss JA. Pharmacologic immunosuppression. *Front Biosci*<2004;9:411–420.

Table 45-4 Infections Seen in SOT Recipients

Bacterial
Methicillin-resistant staphylococcus aureus, vancomycin-resistant enterococcus, Clostridium difficile, Legionella, Mycobacterium tuberculosis, atypical mycobacterium, Nocardia, Pseudomonas, and other
Fungi
Candida, Aspergillus, Cryptococcus, Pneumocystic jiroveci, Mucorales, dematiaceous fungi, Zygomycetes
Endemic mycoses
Histoplasmosis, blastomycosis, coccidioidomycosis
Viruses
Cytomegalovirus, herpes simplex virus, varicella-zoster virus, Epstein-Barr virus, human herpesvirus 6 and 7, Kaposi sarcoma herpesvirus (KSHV), hepatitis C, hepatitis B, adenovirus, respiratory syncytial virus, influenza, parvovirus B19, polymaviruses, arenavirus, West Nile virus, parainfluenza virus, metapneumovirus, coronavirus, rabies, human papillomavirus
Other
Toxoplasmosis gondii, Strongyloides stercoralis, Trypanosoma cruzi, Cryptosporidium

Infection in SOT may be related to a large number of pathogens (Table 45-4). The following discussion is limited to highly significant pathogens.

Bacterial

Healthcare-associated methicillin-resistant *Staphylococcus aureus*(MRSA), vancomycin-resistant enterococci (VRE), and resistant Gram-negative infections continue to be a major concern among transplant programs. Because transplant patients are often transferred from other healthcare facilities to a transplant center, they may be colonized with resistant pathogens not typical of the transplant center. On one liver transplant unit, two extended-spectrum β-lactamase (ESBL)-producing *Escherichia coli*bacteremias were identified within 9 days.[37]These were the first two cases of this pathogen within this healthcare facility and were most likely introduced by a liver transplant candidate who was colonized before admission. MRSA colonization has been associated with the subsequent development of MRSA infection. Enterococcal infections are more common in liver transplant recipients than in other SOT recipients. Russell et al.[38]followed 706 liver transplant candidates or recipients prospectively to determine the cumulative risk of MRSA or VRE infection or death by colonization status. The prevalence of newly detected colonization for MRSA (nares) was 6.7 percent and for VRE (rectal), 14.6 percent. The MRSA-colonized liver transplant population had an increased risk of MRSA infection (adjusted odds ratio [OR] = 15.64; 95 percent confidence interval [CI], 6.63–36.89), but not of death (adjusted OR = 1.00; 95 percent CI, 0.43–2.30), whereas the VRE-colonized population had an increased risk of VRE infection (adjusted OR = 3.61; 95 percent CI, 2.01–6.47) and death (adjusted OR = 2.2; 95 percent CI, 1.27–3.54).[38]When completing the infection prevention risk assessment for a transplant program, the

use of active surveillance swabs and MRSA decolonization for preoperative SOT patients or dialysis patient may be considered. (For additional information, see **75. Enterobacteriaceae**, **76. Enterococci**, **77. Environmental Gram-Negative Bacilli**, and **93. Staphylococci**.)

*Mycobacterium tuberculosis*is a serious opportunistic infection in SOT recipients, with a worldwide incidence of 0.35 to 15 percent.[17]In one review of 476 recipients with tuberculosis infection, 51 percent had pulmonary tuberculosis while 16 percent had disseminated tuberculosis.[17]Clinicians ordering treatment for TB disease or prophylaxis must have a clear understanding of the interactions between immunosuppressive and antituberculosis medications to ensure adequate treatment and immunosuppression. There is concern that isoniazid therapy places transplant recipients at high risk for hepatotoxicity. However, one study demonstrated that clinically significant hepatotoxicity requiring discontinuation of therapy occurred in 2.5 percent of renal, 4.5 percent of heart and lung, and 41 percent of liver transplant recipients.[17]Progression to TB disease may be rapid and the presentation atypical in this immunosuppressed population. In addition, pulmonary TB may coexist with another pulmonary entity. Therefore, diagnosis of another pulmonary entity causing symptoms does not preclude the presence of TB. The SOT recipient with any suspicion of pulmonary tuberculosis should be placed in Airborne Precautions promptly until tuberculosis is ruled out.

Fungal

Invasive *Aspergillus*occurs in 1 to 15 percent of SOT, with lung and heart-lung recipients having the highest risk of occurrence, at 15 to 35 percent.[39]In one study of 1,963 patients undergoing thoracic (heart and/or lung) transplant, *Aspergillus*was identified as the primary pathogen (64.1 percent; 34/53 cases) causing fungal infection.[40]Cystic fibrosis patients undergoing lung transplant have a higher rate of colonization with *Aspergillus fumigatus*before (53 percent) and after (59 percent) and may develop tracheobronchial aspergillosis despite prophylaxis. However, the rate of invasive aspergillosis in cystic fibrosis patients compared with patients without cystic fibrosis is not higher.[39,41]The attributable mortality for invasive aspergillosis in SOT recipients ranges from 64 to 92 percent.[39]Anti-aspergillosis prophylaxis currently is not recommended routinely for SOT recipients; however, targeted prophylaxis for higher risk recipients, such as lung recipients or colonized recipients, is a rational approach. Some prophylactic regimens that have been used are inhaled amphotericin B, itraconazole, parenteral amphotericin formulations, and voriconazole.[39](For additional information, see **78. Fungi**.)

Viral

CMV is a common and important infection among SOT recipients. CMV seroprevalence rates range from 30 to 97 percent in the general population.[42]After primary infection, lifelong latency is established.

Infection may be donor derived, primary, reactivation of latent virus, or superinfection (i.e., acquisition of a new strain of CMV). In addition to CMV directly contributing to morbidity, it may also have an immunomodulatory effect. CMV disease has been found to be an independent risk factor for other infections, such as bacteremia, invasive fungal disease, and EBV-related posttransplant lymphoproliferative disease.[42]CMV has also been implicated as a cause of acute and chronic allograft injury. The highest risk of disease is in a CMV-positive donor and a CMV-negative recipient. Antiviral prophylaxis reduces CMV infection and minimizes the indirect impact. Standard Precautions should be used to prevent transmission.

BK virus (BKV), a human polyomavirus, has emerged as a significant pathogen that may be present in the kidney of the donor or recipient and is believed to have emerged as a result of potent immunosuppressive drugs such as tacrolimus, mycophenolate mofetil, and sirolimus.[43]It is a significant cause of allograft failure in renal transplant recipients.[44]Seroprevalence among the general population ranges from 65 to 90 percent.[45]The natural route of transmission is not known, but urinary shedding and transmission via aerosol and fomites during respiratory infection have been suggested.[46]Blood, semen, genital tissues, and normal skin biopsies have been shown to contain BKV, and transplacental transmission has been documented.[43]In one study, none of 616 renal transplant recipients between 1988 and 1995 had documented BK virus nephropathy, compared with 5 of 70 between 1995 and 1997 (*p*β .00001).[47]There are no published studies describing strategies to prevent transmission of BKV in a healthcare setting and no recommendations for isolation beyond Standard Precautions. The symptom most frequently associated with this virus is an upper respiratory infection, and nearly 100 percent of children by age 9 to 10 have detectable BKV antibody.[48](For additional information, see **80. Herpes Virus**, and **97. Viral Hepatitis**.)

OTHER

*Toxoplasma gondii*is an important pathogen following heart transplant due the cysts' affinity for heart muscle and the ability for transmission from the donor organ.[49]In most seronegative recipients receiving a heart from a seropositive donor, primary infection does occur. Sulfonamide and trimethoprim prophylaxis may be used to prevent transmission and reactivation of *Toxoplasma*infection.

Strongyloides stercoralis, a parasitic roundworm, may cause serious infection in SOT recipients. The highest risk exists during the first 3 months after transplant.[50]Screening should be considered if the candidate is from area endemic for this parasite.

TRANSPLANTATION IN CANDIDATES WITH HUMAN IMMUNODEFICIENCY VIRUS INFECTION

With the highly active antiretroviral therapy, HIV disease has become a chronic, manageable disease, making SOT a realistic option. In 2001, a successful heart transplant was performed in a patient with advanced HIV disease.[51]Survival of HIV-positive liver transplant recipients has been shown to be the same as that of HIV-negative recipients.[52]There are potent interactions that can occur between antiretrovirals and immunosuppressive agents, therefore dosing must be carefully adjusted and monitored.

INFECTION PREVENTION

Monitoring Infection Rates

An infection control risk assessment (ICRA) should be completed for the specific SOT program considering such issues as the type of transplant performed, the environment, and prior infection rates. The ICRA should be used to decide types of infections, processes, practices, and risks to be monitored.

Within the National Healthcare Safety Network (NHSN), the SOT unit is not a distinct category—such units are classified as either surgical or medical/surgical intensive care units. When benchmarking against NHSN, you are comparing against hospitals that may or may not provide care to this

immunosuppressed population of patients. Therefore, internal benchmarking is important when monitoring trends in HAIs. In today's culture of zero tolerance for HAIs, the zero goal is reasonable when conducting surveillance for typical HAIs in this population.

Healthcare Personnel and Household Contacts of Solid Organ Transplantation Recipients and Immunizations

It is essential that healthcare personnel providing care to SOT recipients be adherent with current immunization recommendations: annual influenza vaccine; Hepatitis B series; varicella; measles, mumps, and rubella if not already immune; and a single dose of Tdap.[53,54] In an influenza outbreak on a 12-bed SOT unit, four patients were diagnosed with influenza A during a period of 4 days, and three employees presented with clinical symptoms of influenza.[55] Healthcare personnel adherence to recommended immunizations will ensure vaccine-preventable outbreaks do not occur in this high-risk population.

Family members and household contacts of SOT recipients should receive the full complement of vaccine to protect the recipient. Some live vaccines can be safely administered to the close contacts of recipients, whereas others may place the recipient at risk. It is advisable that the specific risks of each immunization be reviewed with the family member or household contact to ensure the recipient is not placed at risk. (For additional information, see **103. Immunization of Healthcare Personnel**.)

General Infection Prevention Practices

- Adherence to hand hygiene practices, including not wearing artificial nails.[56]
- Adherence to published infection prevention guidelines.
- Adherence to Standard Precautions and Transmission-based Precautions (i.e., Contact, Droplet, Airborne).[57]
- Upon admission, review medical record for history of resistant organism or other infection requiring Transmission-based Precautions.
- Adherence to practices to prevent transmission of resistant pathogens.
- Minimize time spent in crowded rooms.
- When completing the program ICRA, consideration may be given to the use of a low microbe diet (i.e., no fresh salads and fruits), no foods that contain mold or fungi (e.g., blue cheese, pepper) due to potential *Aspergillus*contamination.[58]
- Routine oral hygiene with soft toothbrush and good personal hygiene.
- Monitor infection prevention practices and processes to assure adherence.

Infection Prevention for Visitors

Transplant patients and families are often hospitalized at a distance from their homes and support systems and therefore look for support among other transplant patients and/or families.

- Educate family and other visitors on their role in preventing the transmission of colonization and infection.
- Provide instructions on hand hygiene and isolation practices both verbally and in writing.
- Restrict visitors with upper or lower respiratory tract infections.
- Screen recipients of live virus vaccines before visiting.

Environmental Infection Prevention

General Housekeeping

- Patient areas should be cleaned daily.
- Horizontal surfaces and vents should be damp dusted to avoid dispersal of dust.
- Surfaces selected for transplant areas should be nonporous and easily cleaned.
- Carpeting and other items that collect dust are not recommended for use in patient rooms or corridors of transplant units.[59]
- Vacuum cleaners should be maintained in good repair with HEPA filters to minimize dispersion of dust.[59]
- Infection preventionists (IPs) should continually assess the environment for issues that may place the SOT donor or recipient at risk for fungal and other infection.

(For additional information see **115. Water Systems Issues and Prevention of Waterborne Infectious Diseases in Healthcare Facilities** and **116. Construction and Renovation**.)

Construction, Remediation, and Air Handling

IPs must be included in the comprehensive and interdisciplinary planning before construction or remediation to ensure the design of a unit promotes infection prevention and that proper precautions are taken to prevent HAIs throughout the project. Construction and remediation place SOT recipients at risk for both airborne and waterborne pathogens. HAIs epidemiologically linked to construction has been well documented in the literature.[60]Although aspergillosis can result from exposure outside of the hospital or preexisting colonization, healthcare facilities should make every effort to prevent exposure within the facility.

- Strict adherence to the ICRA before construction or remediation.[59,60,61]
- Areas of the healthcare facility that may be accessible to SOT recipients must be considered high risk when completing the ICRA, as should the area where patient is housed (i.e., radiology, physical therapy).
- The IP should monitor for breaches in practice on a regular basis and educate healthcare personnel as to the risks that construction and renovation may pose to patients and the need to be observant for gaps in barriers and practices.
- Construction or excavation outside of the healthcare facility but within close proximity to the building may pose a risk to SOT recipient and such projects should be assessed for risk.
- Conduct surveillance for fungal and waterborne hospital-associated infection that may be related to construction or renovation.
- Include an Airborne Precautions room in new construction for SOT units.
- There are no specific recommendations for environment air control for SOT recipients. Some SOT hospitals that have had problems with healthcare-associated fungal infection have implemented higher air controls, such as point-of-use HEPA filters, to prevent early postoperative exposure to fungi.[62]

  Consider the type of transplant being done and the facility/community history of hospital-associated fungal infection when making decisions related to environment air controls.

- When completing ICRA, consider that vibrations related to construction may release biofilm into the water distribution system.

Water Distribution Systems

Water distribution systems in healthcare facilities have long been associated with infections related to waterborne pathogens. The most important of these in the SOT patient is *Legionella*. *Legionella*should be included in the differential diagnosis of healthcare-associated pneumonias in SOT recipients. Although the majority of cases of healthcare-assocaited *Legionella pneumonia*are caused by *Legionella pneumophila*serogroup 1, other serogroups and species may cause pneumonia in SOT recipients.[63]

- On-site *Legionella* diagnostic testing: If *Legionella pneumophila* serogroup 1 is identified through environmental surveillance, urinary antigen testing should be available on-site.[64]
- Consider periodic culturing of the water distribution system for *Legionella*.[65]Although the CDC recommends this as a possible approach, there are areas of the country and healthcare systems that recommend periodic culturing of water in all transplant facilities.[64,66]
- If *Legionella* species are identified in the water system, a risk assessment based on findings should be conducted and decontamination implemented.[64,65]
- A risk assessment should be conducted when there is a disruption to water services.
- If the water is not used for any period of time, the waterlines should be flushed to ensure stagnant water will not be used.

(For additional information, see **84. Legionella pneumophila**.)

Storage of Organs and Tissues

In 2004, rabies encephalitis was diagnosed in an organ donor and the associated three transplant recipients. A fourth recipient who received an organ from a different donor was confirmed positive for rabies. Upon investigation, it was discovered that an artery segment from the original donor was stored and used during the SOT on the fourth recipient.[67]Although UNOS provides guidance on storage and transport of organs, tissue storage guidelines must also be adhered to and are available via the Association of periOperative Registered Nurses (AORN) and The Joint Commission (TJC).

Patient Education for Safe Living

The International Transplant Nurses Society (ITNS) is an excellent resource for patient/family education material. Education pamphlets for the heart, liver, and kidney/pancreas transplant recipient are available on the Society's website. Practices for preventing infection after discharge are discussed in these pamphlets. Education to prevent opportunistic, community-associated, and HAIs should be addressed with SOT recipients before discharge. These instructions should include:

- Impact of immunosuppressive regimen on infection risk.
- Recognition of signs and symptoms of infection.
- Aseptic wound care.
- Review of hand hygiene with recipient and close contacts.
- Social distancing during cold/flu seasons, including ill household members.

- Encourage family members and household contacts to update immunizations and receive annual influenza vaccine. If receiving live, attenuated vaccine, the specific risks of the vaccine should be discussed with the healthcare provider.
- Safe pet handling. Wash hands before and after contact with pets. Avoid handling animal waste, such as that found in bird cages, chicken coops, fish or turtle tanks, and cat litter boxes. Do not store litter boxes in food preparation or eating areas. If you must handle animal waste, be cautious (i.e., wear gloves and a mask when changing litter box). Avoid handling reptiles (e.g., lizards, snakes, turtles), baby chicks and ducklings, hamsters, exotic pets, and wild animals. Ensure pets receive regular veterinarian care.
- When gardening, wear gloves and wash your hands frequently. Consider avoiding gardening during the first 3 to 6 months after transplant. Avoid compost piles, wet leaves, and rotting organic materials, which may carry mold. Wear a mask if the activity is unavoidable.
- Avoid construction and excavation sites and other dust-laden environments where fungal spores may be high.
- Avoid small standing bodies of water, such as ponds or small lakes, that may contain infectious organisms or swimming in water that may be contaminated with human or animal waste.
- Practice safe sex (e.g., condom use, limiting partners).
- Safe handling and storage of food. Avoid raw or undercooked meat, fish, eggs, poultry (e.g., sushi). Avoid milk, juice/cider, and soft cheeses that are not pasteurized. Thoroughly wash fruits and vegetables. Do not share eating utensils and drinks with others.
- Assess the source of drinking water and provide instructions to ensure safe water consumptions (e.g., testing well water, boiling questionable water, avoiding water from questionable sources). Consume water and ice only from safe sources.
- Decrease molds in the household by maintaining a sanitary environment. Avoid use of sponges.
- Avoid mosquito bites.
- Encourage family, significant others to receive influenza immunization.
- Encourage good hygiene practices, including skin care.
- Avoid smoking and environmental smoke.
- SOT recipients planning to travel to foreign countries should discuss the potential risks with their healthcare provider well in advance.

Conclusions

Although infection prevention practices are known to improve patient outcomes, both practice gaps and the net state of immunosuppression continue to place the SOT recipient at risk for infection. IPs must strive to create a culture of infection prevention within the SOT program by working with all healthcare personnel who have an impact on the program. When considering the limited organ supply and the impact of infection on the SOT recipient, it is apparent that a culture of infection prevention is critical to improving outcomes.

Future Trends

The critical and delicate balance between immunosuppressive therapy and opportunistic infection will continue to be studied, as will preventative strategies such as immunization and preemptive and prophylaxis therapy. Research is demonstrating that immunosuppression minimization strategies are effective. Several transplant centers have successfully treated liver transplant patients so that they have very low or undetectable levels of tacrolimus after initial therapy.[68] Other centers are reducing or eliminating corticosteroids, especially in pediatric populations.[68] Perhaps, in the future, we will have better methods of defining the individualized level of immunosuppressive therapy needed to prevent rejection and accessible multiassay diagnostic screens to identify active or latent infection in both the donor and the candidate/recipient.

International Perspective

With international travel becoming more common and the increased numbers of international SOT programs, including some within developing countries, there may be a resultant impact on emerging opportunistic or new infections.

Internationally, there is concern about the emergence of a pandemic influenza strain. Previous pandemics have not occurred in an era in which our population was iatrogenically immunocompromised.[69] Although the impact cannot be inferred, existing science can suggest that transplant recipients may be more likely to develop symptomatic disease and shed larger amounts of virus for prolonged periods, have more opportunities for exposure due to frequent healthcare contact, have higher mortality, and find vaccination and antiviral strategies to be less effective.[70]

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Hematopoietic Stem Cell Transplantation

Author(s): Nedra D. Marion, RN, BSN, MPA, CIC
Manager, Department of Infection Control and Epidemiology

The Nebraska Medical Center
Omaha, NE

Kim Schmit-Pokorny, RN, MSN, OCN®
Manager

Blood and Marrow Transplantation Program
Oncology/Hematology Division
University of Nebraska Medical Center
Omaha, NE

Dawn Jourdan, RN, BSN
Clinical Quality Coordinator

The Nebraska Medical Center
Omaha, NE

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Abstract

Infectious complications remain a limiting factor to hematopoietic stem cell transplantation. Infections are related to a variety of risk factors, including the type of transplant and preparative regimen, the serologic status of the donor and recipient, the presence of graft versus host disease, and numerous environmental factors. Preventive measures should emphasize provision of a protective environment, appropriate use of prophylactic anti-infective agents, and meticulous attention to infection prevention practices, such as hand hygiene, device management, and visitation regulation. After transplantation, immunizations and lifestyle issues should be addressed to minimize late infectious complications.

Key Concepts

- Hematopoietic stem cell transplant recipients are at increased risk of infection for a variety of reasons, including neutropenia, mucositis, and the presence of indwelling catheters.
- A protective environment should be available for Hematopoietic stem cell transplant inpatients that includes positive-pressure, high-efficiency particulate absorption-filtered air handling; *Legionella*-free water supply; and specially trained personnel who adopt a team approach to infection prevention concerns.
- The prudent application of prophylactic anti-infective agents can decrease the incidence of bacterial, fungal, and viral infections.
- Key infection prevention measures include scrupulous attention to hand hygiene and respiratory etiquette, vigilant care in the insertion and management of intravascular catheters and other medical devices, dust control, and screening and regulation of visitors and personnel.

Background

During the past several decades, Hematopoietic stem cell transplant (HSCT) has progressed from being an infrequently used, desperate therapeutic measure for otherwise fatal conditions to a frequently employed mainstay of therapy for a variety of diseases. Indications for HSCT include both hematologic and solid organ malignancies, as well as congenital and acquired nonmalignant diseases.[1,2] More than 17,000 transplants are performed annually in the United States. Unfortunately, infectious complications remain a major limiting factor. From 2009 to 2010, infection was the cause of death in 7, 13, and 18 percent of patients undergoing autologous, related-allogeneic, and unrelated-allogeneic HSCT procedures, respectively.[3]

Basic Principles

HSCTs are classified as autologous, allogeneic, or syngeneic based on the source of the stem cells, which can be obtained from the marrow, peripheral blood, or umbilical blood. In an autologous transplant, the stem cells are collected from the patient. Stem cells collected from a related or unrelated donor are used for allogeneic transplants. If stem cells are collected from an identical twin donor, it is called a syngeneic transplant.[4] The closeness of match between donor and recipient influences the degree of graft versus host disease (GVHD), the amount of immunosuppressive agents administered, and thus the risk of infectious complications. GVHD occurs when donor immune cells recognize the recipient as foreign and attack the host's (recipient's) cells. GVHD is divided into acute and chronic GVHD.[5]

TRANSPLANT PROCEDURE

Patients are prepared for HSCT by aggressive treatment of the underlying disease with irradiation (total body or total lymphoid), cytotoxic chemotherapy, or biologic agents (e.g., antithymocyte globulin, monoclonal antibodies). The preparative regimen usually results in pancytopenia and a breakdown of mucosal/skin barriers. Stem cells, obtained from a donor or previously cryopreserved from the patient, are infused intravenously. Neutrophil recovery following transplant depends on the type of graft. Patients who receive peripheral blood stem cells mobilized with filgrastim typically recover neutrophils approximately 14 days following infusion. However, patients receiving bone marrow may take about 3 weeks to recover, and cord blood grafts take around 4 weeks.[6] However, despite engraftment, all

components of the immune system remain deficient for variable amounts of time after HSCT. In the absence of GVHD, granulocyte function may remain abnormal for 6 to 12 months. B-cell function remains abnormal for a prolonged period, and antibody response to immunization after HSCT is usually lower than in normal hosts.[6,7] Immunoglobulin G (IgG) and immunoglobulin A (IgA) production may be abnormal for 1 to 2 years after HSCT. CD4 cells (T-helper cells) and response to recall antigens remains low for several years.[6,7,8] Conversely, CD8 cells (T-suppressor cells) rebound relatively quickly with a resultant inversion of the normal CD4:CD8 ratio.[8,9,10] Complement levels and function generally return to normal after transplant.[11]

GRAFT VERSUS HOST DISEASE

The immunopathophysiology of GVHD is complex and beyond the scope of this chapter. GVHD occurs in up to 40 percent of transplants from a sibling donor and 70 percent of unrelated transplant recipients.[5] GVHD is divided into acute and chronic forms; however, there may be an overlap of both acute and chronic GVHD.[5] Acute GVHD often involves the liver, skin, and gastrointestinal tract, whereas chronic GVHD involves multiple organ systems. GVHD results in a disruption of the barrier function of organs and a corresponding increase in the risk of infection.[5] In addition, GVHD predisposes the transplant recipient to a variety of infectious complications, such as cytomegalovirus (CMV), pneumonia, and invasive fungal infections, as well as noninfectious complications such as bronchiolitis obliterans and idiopathic interstitial pneumonia. GVHD also causes functional asplenia, resulting in an increased risk of infection due to encapsulated organisms such as pneumococci and *Haemophilus* spp.[5,6]

Immunological Defects And Associated Infectious Complications

Immunological defects, causes of defects, and associated infectious complications are summarized in Table 46-1. Infectious complications associated with HSCT are related to a variety of risk factors and tend to occur at certain phases of the transplant process. Factors affecting the incidence of infection include the type of transplant and preparative regimen, the serologic status of the donor and recipient, the use of prophylactic anti-infective agents, the presence of GVHD, and various environmental factors. Figure 46-1 illustrates the relative frequency and timing of common infections associated with HSCT. In the pre-transplant stage (day 10 to 0), immunological defects are dependent on the underlying disease and preparative regimen; if present, the defects are a result of disruption of anatomic barriers and neutropenia. The majority of infections at this stage consist of local bacterial infections of the skin, urinary tract, or respiratory tract. In addition, central venous catheters usually are used in the preparative period to administer chemotherapeutic agents and other medications and blood products. Subcutaneously tunneled and cuffed central venous catheters are associated with an infection rate of approximately 1.6 bloodstream infections per 1,000 catheter days, whereas totally implanted catheters are associated with approximately 0.1 bloodstream infection per 1,000 catheter days.[12] In stage I, the pre-engraftment phase (day 0 to 30), almost all subjects experience profound neutropenia and disruption of anatomic barriers. The risk of infection associated with neutropenia is great when neutrophil counts are below 500/mm^3 and is greatest when counts are below 100/mm^3.[13] In addition, the risk of infection is greatest in patients who experience an abrupt decrease in neutrophil count.[14] The rate

of infection during neutropenia is approximately 45 to 50 infections/1000 days.[15] Pathogens responsible for infections in the first part of the pre-engraftment stage usually are Gram-negative aerobic bacilli and Gram-positive cocci. Toward the latter part of the pre-engraftment stage, opportunistic fungi, such as *Aspergillus*, become more prominent causes of disease. Herpes simplex virus (HSV) is the most common viral infection in the early transplant period. In stage II, the postengraftment phase (day 30 to 100), neutropenia and mucosal and skin barrier breakdown usually have resolved. However, acute GVHD can result in significant dermatologic and gastrointestinal barrier dysfunction. The primary immunological deficiency at this stage of HSCT is a profound impairment in cellular and humoral immunity. CMV, adenovirus, BK polyomavirus, respiratory syncytial virus (RSV), and other respiratory viruses, such as influenza and parainfluenza, cause significant disease during this stage. Pneumocystis and toxoplasmosis present during this stage. Patients also continue to experience fungal infections, though with less frequency than during the pre-engraftment phase. In stage III, the late posttransplant phase (>100 days), subjects with chronic GVHD may have breakdown of mucosal and skin barriers and thus be predisposed to infection. Cell-mediated immunity and humoral immunity may continue to function abnormally. The infections most frequently noted in this group of patients are varicella zoster (shingles) and localized infection of the skin and respiratory tract. Encapsulated bacteria can cause overwhelming disease. The most common fungal infection observed is oral candidiasis.

Table 46-1 Immunologic Defects Associated with Hematopoietic Stem Cell Transplantation

Immunologic Defect	Etiology	Pathogen/Infection Associated with the Immunologic Defect
Disruption of skin and mucous membranes	Cytotoxic chemotherapy Irradiation GVHD Intravascular catheters Urinary catheters HSV	Bacterial infections from skin (primarily Gram-positive cocci) Bacterial infections from gastrointestinal tract (primarily Gram-negative bacilli) *Candida*infection from gastrointestinal tract or intravascular catheters Gram-negative enteric organisms or yeast from urinary catheters
Neutropenia	Cytotoxic chemotherapy Irradiation Underlying disease	Gram-negative aerobic bacilli, Gram-positive cocci, *Candida*spp., *Aspergillus*spp., HSV
Cell-mediated immunity	Cytotoxic chemotherapy Irradiation Underlying disease GVHD	CMV, EBV, adenovirus, RSV and other respiratory viruses, *Pneumocystis jiroveci, Listeria monocytogenes, Mycobacterium tuberculosis, Toxoplasma gondii*

Humoral immunity	Cytotoxic chemotherapy Irradiation Splenectomy GVHD	Encapsulated bacteria (*Streptococcus pneumonia, Neisseria meningitidis, Haemophilus influenzae*)

CMV, cytomegalovirus; EBV, Epstein-Barr virus; HSV, herpes simplex virus; RSV, respiratory syncytial virus.

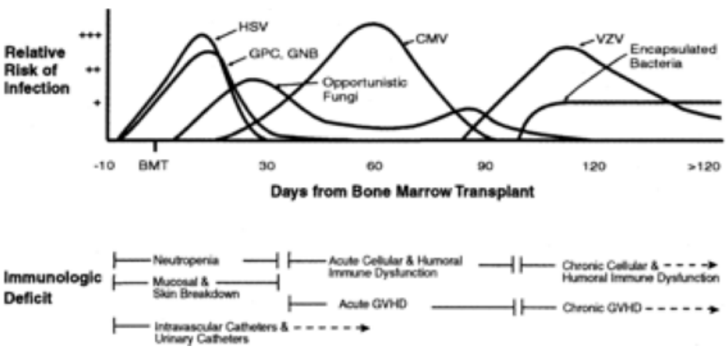

Figure 46-1.

Relative frequency of infection in hematopoietic stem cell transplant (HSCT) recipients. The time course of HSCT is associated with specific immunologic deficits that predispose the patient to specific infections. HSV, herpes simplex virus; GPC, Gram-positive cocci; GNB, Gram-negative bacilli; CMV, cytomegalovirus; GVHD, graft versus host disease; VZV, varicella-zoster virus; pretransplant stage, day –10 to 0; Stage I (pre-engraftment phase), day 0 to 30; Stage II (postengraftment phase, day 30 to 100; Stage III (late posttransplant), >100 days.[6]

View Image

Specific Infections In Hematopoietic Stem Cell Transplantation

BACTERIAL INFECTIONS

The etiology of bacterial infections in HSCT patients has changed over the last 20 years. Infections caused by Gram-negative organisms has decreased from approximately 70 to 30 percent.[16,17]The extensive use of central venous catheters and prophylactic administration of oral fluoroquinolones has been largely responsible for this etiologic shift. Staphylococci, predominantly coagulase-negative staphylococci, are the most common cause of bacteremia in HSCT patients.[16]Differentiating true pathogens from culture contaminants is difficult, and improved diagnostic techniques are needed.[18]In some transplant centers, *Streptococcusviridans* has emerged as an important pathogen and can result in fulminant infections associated with significant mortality.[19]In addition, partially because of the widespread empiric use of vancomycin, vancomycin-resistant enterococci have become problematic in many centers.[16,20]Although the overall prevalence of infections due to enteric Gram-negative organisms has declined, infections due to highly antibiotic-resistant organisms such as *Acinetobacter* spp. and *Stenotrophomonas* spp. appear to be on the rise.[21]Outbreaks of extended-spectrum beta-lactamase-producing *Enterobacteriaceae* in HSCT patients also have been reported.[22]

FUNGAL INFECTIONS

Fungal infections pose a serious risk to HSCT patients and are associated with a high risk of morbidity and mortality.[23] The incidence of invasive fungal infections varies from facility to facility and is likely influenced by factors such as patient populations, transplant protocols used at each facility and the methods used for detection and diagnosis of invasive fungal infections.[24] Risk factors for the development of invasive fungal disease include neutropenia, cytotoxic chemotherapy, mucositis, indwelling intravascular catheters, and therapy with broad spectrum antibiotics or corticosteroids for treatment of GVHD. (For additional information, see **78. Fungi**, and **116 Construction and Renovation**.)

Candida

Before the use of prophylactic antifungal agents, *Candida* infections occurred in approximately 11 percent of HSCT patients.[25] However, prophylaxis with fluconazole has dramatically decreased the incidence of *Candida albicans* infections.[26] Non-*albicans* species of *Candida* (such as *C. tropicalis, C. parapsilosis*, and *C. krusei*) are becoming increasingly prevalent.[27] The most common sources for candidemia are the gastrointestinal tract and intravascular catheters. Unfortunately, fewer than 50 percent of patients with hematogenously disseminated candidiasis have positive blood cultures,[28,29] so empiric antifungal therapy with imidazole agents (such as fluconazole), amphotericin B, or echinocandins frequently is used in febrile HSCT patients. Several species of *Candida* (e.g., *C. krusei, C. glabrata*) are intrinsically less susceptible to imidazole antifungals, and there are increasing reports of resistant *C. albicans*.[30] Some institutions that have employed fluconazole prophylactically have observed an increased incidence of infections due to *C. krusei*.[31] The traditional treatment of choice for invasive candidal infection has been amphotericin B, which unfortunately often is associated with infusional side effects and nephrotoxicity. In many centers, liposomal amphotericin B has replaced standard amphotericin B. Several studies indicate comparable efficacy between amphotericin B and fluconazole for the treatment of candidiasis in neutropenic and non-neutropenic patients.[32,33] Newer drugs such as echinocandins are also increasingly used to treat invasive candidiasis and may be better tolerated than amphotericin B.[34,35]

Aspergillus

Approximately 5 to 10 percent of HSCT recipients develop infections due to *Aspergillus*.[36] Invasive aspergillosis has a mortality rate of 80 to 90 percent.[37] *Aspergillus* appears to have a bimodal incidence distribution, with peaks at days 16 and 96, due to neutropenia and GVHD, respectively.[38] *A. fumigatus* and *A. flavus* account for most cases of invasive aspergillosis;[39] however, *A. niger, A. terreus*, and *A. ustus* also have been recognized.[24,40] The respiratory tract is the major portal of entry for *Aspergillus*, and the most common clinical presentation of aspergillosis is pneumonia or sinusitis. In a patient with concomitant pneumonia and sinusitis, fungal disease should be suspected.[29] *Aspergillus* can disseminate to the brain and other body sites including skin, heart, kidney, eyes, and the gastrointestinal tract.[29] Outbreaks of aspergillosis have been associated with construction/renovation projects in which airborne dust levels increase.[41,42,43] Data indicate aspergillosis may be contracted from the hospital water supply,[43] however the risk appears to be very low.[44]

The diagnosis of aspergillosis is challenging. Usually, invasive disease is suspected on the basis of radiologic findings with a computed tomography scan being preferred over traditional chest radiograph. Definitive diagnosis requires isolation of the mold from culture or histologic demonstration of invasive disease. Isolation of *Aspergillus* from bronchoalveolar lavage (BAL) fluid is highly suggestive of pulmonary aspergillosis.[45] Because the microbiologic diagnosis of aspergillosis at an early stage is difficult, alternative molecular-based diagnostic tests have been developed. Galactomannan enzyme immunoassay testing has proved helpful in the diagnosis of invasive aspergillosis. β-(1-3)- D-glucan (BDG) also can aid in the early diagnosis of aspergillosis; however, it is not specific to *Aspergillus* but detects several fungal pathogens including *Candida* spp., *Aspergillus* spp., *Pneumocystis* spp., and *Fusarium* spp.[23] Nucleic acid polymerase chain reaction (PCR) assays, which appear promising, have not been approved for clinical use.[46] There also has been development of common definitions to guide clinical and epidemiological research.[47] Voriconazole is the drug of choice for the treatment of invasive aspergillosis.[48] For voriconazole intolerance or when liver toxicity is a concern, liposomal amphotericin B may be used for treatment.[37] Several other agents with anti-*Aspergillus* activity, such as posaconazole, caspofungin, and micafungin, also may have a role in the treatment of invasive aspergillosis.[37] New antifungals still in development include isavuconazole, ravuconazole, albaconazole, and aminocandin.[37] In addition, the value of combination therapy is being studied.

HEPA-filter systems and laminar airflow environments appear to offer a degree of protection from aspergillosis.[42,49] However, their value remains questionable due to the cost, little survival benefit, and the increasing trend toward outpatient management of HSCT patients. Some centers employ low-dose intravenous amphotericin B, intranasal amphotericin B, or oral itraconazole for aspergillosis prophylaxis.

Other Fungi

Other fungi increasingly are being reported to cause infection in HSCT patients. Pathogens include *Fusarium* spp., *Alternaria* spp., *Sporium* spp., *Pseudallescheria boydii, Trichosporon* spp., *Saccharomyces* spp., *Penicillium* spp., *Bipolaris* spp., *Curvularia* spp., *Rhodotorula* spp., and *Pityrosporum* spp.[29,50,51]

VIRAL INFECTIONS

Herpes Simplex Virus

Without antiviral prophylaxis, approximately 25 percent of HSCT patients seropositive for HSV develop reactivated infection.[52] Gingivostomatitis is the most common clinical presentation, but HSV also can cause pneumonia, esophagitis, hepatitis, encephalitis, keratitis, and limited or disseminated mucocutaneous infection. Prophylactic acyclovir is highly effective in preventing reactivation of HSV.

Cytomegalovirus

Prior to the use of CMV prophylaxis, CMV was the most common cause of morbidity and mortality following HSCT and occurred in approximately 80 percent of seropositive patients.[53,54] CMV most commonly presents as pneumonitis or gastroenteritis, but it also can cause fever, encephalitis, retinitis, hepatitis, and pancytopenia.[55] In addition, CMV is an immunosuppressive virus and is linked to graft

rejection, GVHD, and other opportunistic infections.[56] CMV pneumonitis is associated with a mortality rate of approximately 50 percent.[53] Patients with CMV pneumonia are generally treated with a combination of ganciclovir and intravenous immunoglobin.[57]

The use of seronegative blood products and leukocyte-depleted blood products has reduced the incidence of CMV disease in seronegative bone marrow transplant (BMT) recipients.[58] The use of ganciclovir can decrease the incidence of CMV-reactivated disease in seropositive BMT recipients.[59,60] Unfortunately, ganciclovir frequently is associated with neutropenia. Many transplant centers have adopted a preemptive treatment strategy that is dependent on the early detection of CMV disease. Highly sensitive, real-time, quantitative PCR assays allow for patients with viral loads above a certain threshold or those with rapidly increasing viral loads to be targeted for anti-CMV treatment.[53,55] Other molecular-based diagnostic techniques include detection of pp65 antigenemia or pp67 mRNA.[61] Unfortunately, CMV remains a major problem for HSCT recipients and treatment with ganciclovir, foscarnet, or cidofovir is associated with high cost and toxicity.

Varicella-Zoster Virus

Prior to the use of acyclovir prophylaxis, varicella-zoster virus (VZV) infection occurred in as many as 50 percent of BMT recipients.[61] In adults, more than 90 percent of VZV infections manifest as herpes zoster and are most likely secondary to reactivation of latent infection.[62] Reactivation rates differ significantly between transplant programs with incidences of 16 to 63 percent reported.[62] Risk factors for VZV reactivation include human leukocyte antigen (HLA) mismatch between donor and recipient and both acute and chronic GVHD.[62] Patients with GVHD experience a higher incidence of disseminated VZV infection.[63] HSCT patients with VZV infection should be cared for using Airborne and Contact Precautions because of the potential for transmission to other susceptible individuals.[64]

Epstein-Barr Virus

Epstein-Barr virus (EBV) can cause posttransplant lymphoproliferative disorders (PTLD) in patients following an allogeneic transplant. PTLD is a potentially life-threatening complication.[65] The incidence of PTLD ranges from 0.2 percent for patients with no risk factors to 8.1 percent for patients with three or four risk factors. Risk factors associated with PTLD include T-cell depletion of the graft, HLA antigen mismatch, GVHD (both acute and chronic), receiving a second transplant, and receiving a transplant after age 50.[66]

Respiratory Viruses

Respiratory viruses such as RSV, influenza, parainfluenza, adenovirus, human metapneumovirus, and rhinovirus can cause infections in HSCT patients ranging from asymptomatic infection to severe pneumonia and death.[67] Human herpes virus-6 can cause pneumonitis and pancytopenia in HSCT patients.[68] (For additional information, see **80. Herpes Virus**, **82. Influenza**, and **90. Respiratory Syncytial Virus**.)

Other Viruses

BK virus is commonly associated with hemorrhagic cystitis and BK virus-associated nephropathy in HSCT patients.[69]

Adenovirus has been associated with gastrointestinal manifestations (colitis), upper and lower respiratory tract disease (pneumonia), renal involvement (hemorrhagic cystitis), and liver involvement (hepatitis).[70,71]

OTHER INFECTIONS

Pneumocystis jirovecii

Chemoprophylaxis, primarily with trimethoprim/sulfamethoxazole has largely eliminated infection caused by *Pneumocystis jirovecii*, previously named *P. carinii*.[72,73] Without prophylaxis, *P. jirovecii* pneumonia (PCP) developed in approximately 7 percent of patients between 40 and 80 days after BMT.[61] PCP is generally interstitial in character, requires BAL for diagnosis and is associated with a high mortality rate.[74]

Toxoplasmosis

Infection with *Toxoplasma gondii* in BMT patients generally results from reactivation of latent infection. The incidence of toxoplasmosis is highest in some European transplant centers where seroprevalence is high. Toxoplasmosis presents most commonly as multiple focal mass central nervous system lesions. However, more diffuse central nervous system disease can occur, as can myocarditis and pneumonitis.[75,76]

Strongyloides stercoralis

Strongyloides can cause a hyperinfection syndrome in immunocompromised hosts characterized by pneumonitis, meningitis, and sepsis due to Gram-negative bacilli.[77] Because *Strongyloides* can persist in a host for decades, a person who lived in an endemic area, such as Africa, Asia, South America, and the southeast United States, remains at risk in the setting of an immunosuppressive condition.[78]

Clostridium difficile

Clostridium difficile infection has been reported in 9 to 13 percent of patients receiving an HSCT.[79,80] Risk factors for development of *C. difficile* infection include acute GVHD, total body irradiation, chemotherapy prior to HSCT, and the use of broad-spectrum antibiotics.[79,80] Patients are at greatest risk during the first month following HSCT.[79,80]

Prevention Of Infection And Specific Infection Prevention Considerations

Although extensive clinical experience has been accumulated regarding the infectious risks associated with HSCT and means to minimize those risks, there are limited data from randomized controlled trials on the issue of infection prevention in this population. In general, there is wide variation among centers regarding infection prevention practices.[81] In an attempt to standardize practice and improve infection

prevention efforts in HSCT, nine organizations, including the Center for International Blood and Marrow Transplant Research (CIBMTR), American Society for Blood and Marrow Transplantation (ASBMT), U.S.Centers for Disease Control and Prevention (CDC), and Infectious Diseases Society for America (IDSA) published a comprehensive review of the available literature and formulated an evidence-based guideline.[6] The following discussion summarizes the infection prevention recommendations of this guideline. Table 46-2 delineates the rating system used to determine the strength of recommendation and the quality of supporting evidence. Table 46-3 lists the specific CDC/IDSA/ASBMT infection prevention and control recommendations and the strength of the recommendation. Recommendations regarding specific organisms are not found in this section or Table 46-3 but are covered in depth in other chapters of the *APIC Text*. However, because community respiratory viruses pose such a unique threat to HSCT recipients, prevention of infection by these viruses is discussed briefly.

Table 46-2 Rating System for Determining Strength of Recommendation and Quality of Supporting Evidence

Category	Definition	Recommendation
A	Strong evidence for efficacy and substantial clinical benefit	Strongly recommended
B	Strong or moderate evidence for efficacy, but only limited clinical benefit	Generally recommended
C	Insufficient evidence for efficacy or efficacy does not outweigh possible adverse consequences or cost	Optional
D	Moderate evidence against efficacy or for adverse outcome	Generally not recommended
E	Strong evidence against efficacy or for adverse outcome	Never recommended
I	Evidence from at least one well-executed randomized controlled trial	
II	Evidence from at least one well-designed clinical trial without randomization	
III	Expert opinion of respected authorities or descriptive studies	

Table 46-3 Summary of Recommendations Regarding Infection Prevention Activities for HSCT Centers

Recommendation	Strength of Recommendation
Room Ventilation	
Published guidelines should be followed for hospital room design and ventilation	BIII
Allogeneic HSCT recipients should be housed in rooms with at least 12 air changes per hour and central or point-of-use HEPA filtration with 99.97% efficiency capable of removing particles ≥0.3 µm	AIII
When portable industrial grade HEPA filtration devices are used to supplement air filtration, they should be located centrally in the room	BIII
Laminar airflow rooms are not necessary and are not recommended for new construction	DII
Birds should be prevented from nesting near and gaining access to air intake ducts	AII
Hospital rooms should have directed airflow: air intake at one side, air exhaust on opposite side	BIII

Hospital rooms should be well sealed (windows, electrical outlets, floors, and ceiling)	BIII
HSCT rooms should be maintained at positive pressure (≥2.5 Pa) compared to the corridor	BIII
Backup emergency power and redundant air-handling systems should be available and protocols for maintenance and shutdown should be formulated	BIII
Replace air filters regularly per manufacturer's recommendations and monitor filtration efficiency to determine replacement during ongoing construction	AIII
Continuous pressure monitoring of occupied rooms	BIII
Place HSCT patients requiring Airborne Precautions in a protective environment airborne infection isolation room with an anteroom or a standard airborne infection isolation room with a portable industrial-grade HEPA filter	BIII
Construction, Renovation, and Building	
Published guidelines regarding environmental controls during construction should be followed	AIII
HSCT recipients should avoid construction and renovation areas	AIII
An infection control risk assessment should be planned prior to construction or renovation	AIII
During construction and renovation, intensified dust control measures should be enacted	AIII
Construction planning committees should be multidisciplinary and include infection prevention representatives	AIII
Air intake should be sealed during outdoor construction and demolition	BIII
Emergency exits should be weather stripped or stairwell air should be filtered to level of hospital air	BIII
False ceilings should be avoided	BII
During construction, rigid, dustproof barriers should be erected between patient care and construction areas	BIII
Opening and closing of doors or other barriers that might cause dust entry into patient care areas should be minimized	BIII
Specific corridors, entrances, exits, and elevators should be dedicated for construction use	BIII
Hospital construction areas should have negative air pressure relative to HSCT patient care areas	AII
Air from construction zones should be exhausted outside or HEPA filtered	BIII
Standard surgical masks provide negligible protection for HSCT recipients against fungal spores	DIII
Newly constructed or renovated areas should be cleaned before patients enter	AIII
Test and correctly adjust ventilation, direction of airflow and room pressurization before patients enter	BIII
Decontamination of fungal-contaminated materials that cannot be removed and replaced should be performed with copper-8-quinolinolate after cleaning	BIII
Cleaning	
HSCT centers should be cleaned at least once per day with an FDA/EPA-approved disinfectant	BIII
Patients should not be exposed to activities that could cause aerosolization of fungal spores (i.e., vacuuming)	EIII

Water leaks should be cleaned and repaired within 72 hours to prevent mold proliferation	BIII
Moisture meters should be used to guide decision-making in removal of potentially water-penetrated materials	BIII
Flooring and finishes should be nonporous, scrubbable, and easily disinfected	BIII
Thorough cleaning during and after construction and renovation is critical	BIII
Isolation and Barrier Precautions	
HSCT center personnel should follow CDC guidelines for prevention of healthcare-associated infection	AIII
HSCT patients should be housed in private rooms	BIII
Standard Precautions should be practiced if contact with blood or body fluids is anticipated	AIII
When indicated, Airborne, Contact, or Droplet Precautions should be used	AIII
HSCT recipients may benefit from wearing a mask or N95 respirator when exiting their rooms before engraftment	CIII
HSCT patients should avoid crowded areas of the hospital in order to minimize contact with other persons	BIII
Hand Hygiene	
All HSCT personnel and other persons entering HSCT patient rooms should follow CDC hand hygiene guidelines	AI
HSCT recipients should follow good hand hygiene practices	BIII
Antimicrobial soap or alcohol-based hand rubs should be used for hand hygiene (see CDC Guidelines for Hand Hygiene in Healthcare Settings - Recommendations regarding *C. difficile*[91])	AII
Gloves are not a replacement for hand hygiene, and hand hygiene should be practiced before and after glove use	AI
Gloves should be changed between patients and if moving from a contaminated body site to a clean body site	AI
Artificial fingernails or nail extenders should not be worn by HSCT personnel	EIII
Hands should be washed using soap and water when visibly dirty or soiled with blood or body fluids	AI
Equipment	
Equipment should be sterilized or disinfected using EPA-registered compounds as directed by established guidelines	AIII
Wound dressing supplies should be monitored to detect mold contamination	BII
Bandages and dressings should be discarded if they are out of date, have damaged packaging, or are visually contaminated	BIII
Arm boards should be changed frequently, and only sterile dressing materials should be used	BIII
Unsterile tongue depressors should not be used as splints for intravenous catheter sites	DII
Patient rooms and HSCT center hallways should not be carpeted	DIII
Plants, Play Areas, and Toys	

Live plants and dried, fresh flowers or soil-based material should not be allowed in rooms of HSCT patients during conditioning or after HSCT	DIII
Published recommendations for washing and disinfecting toys should be followed	BIII
Play areas for pediatric HSCT patients should be disinfected at least weekly and as needed	BIII
Only toys and games that can be kept clean and disinfected should be allowed in the HSCT center	BIII
Toys and games should be cleaned and disinfected at least weekly and as needed	BIII
Cloth or plush toys should be washed in a hot cycle washing machine or dry cleaned at least weekly and as needed	BIII
Hard plastic toys should be washed with soap and water and immersed in a mild bleach solution and air dried or washed in the hot cycle of a washing machine	BIII
Infants, toddlers, and children who put toys in their mouths should not share toys	BIII
Disposable play items should be offered when possible	BIII
Toys that cannot be cleaned and disinfected after use should be discarded	BIII
Water-retaining bath toys should be avoided	DII
Occupational and physical therapy items should be cleaned and disinfected according to established guidelines	BIII
Soil-based items (clay) should be avoided	DIII
Healthcare Workers	
HSCT centers should provide a comprehensive employee policy with current CDC guidelines regarding vaccination and occupational health	BIII
Every effort should be made to restrict HCP with infections that are potentially transmissible from direct patient care	AII
Recommendations regarding duration of work restriction should be followed	BIII
HCP with bloodborne viruses should not be restricted from patient contact	DIII
HCP should preferentially receive inactivated vaccinations to minimize the theoretical risk of transmission of vaccine virus	AIII
Work exclusion policies should be designed to promote reporting of illness and exposure	AII
Visitors	
All visitors should be screened by trained HCP for potentially infectious conditions according to policy	BIII
Visitors with potentially communicable diseases should not be allowed direct contact with HSCT patients	BII
There is no minimum age limit for visitors; however, all visitors should have the capacity to understand and follow hand hygiene and isolation procedures	AIII
The number of visitors at any one time should be restricted to a number that allows for appropriate screening and adequate education	BIII
Patient Skin and Oral Care	
HSCT recipients should bathe daily with chlorhexidine	BIII

During periods of neutropenia, potential sites of infection (perineum, catheter sites, etc.) should be inspected daily	BIII
Perineal hygiene should be maintained	BIII
Females should wipe the perineum from anterior to posterior to prevent fecal contamination of the urethra	AIII
Menstruating women should not use tampons	DIII
Rectal thermometers, enemas, suppositories, anal sexual penetration, and rectal exams should be avoided	DIII
Good oral and dental hygiene should be maintained for at least the first year posttransplant	AIII
Dental evaluation and relevant treatment should be performed ideally, 10 to 14 days before the transplant conditioning regimen is begun	AIII
HSCT recipients with mucositis should perform oral rinses four to six times per day	AIII
A soft toothbrush should be used to clean teeth at least twice per day	BIII
A toothette stick can be used for patients who do not tolerate tooth brushing	CIII
Use of toothpaste is optional	CIII
Dental flossing should be performed daily if it can be done without trauma	BIII
Routine dental supervision is advised	BIII
During periods of mucositis, fixed appliances should not be worn	DIII
Removal of fixed appliances should be coordinated with the patient's dentist and transplant team	BIII
Dentures may be worn when HSCT patients are at risk for mucositis (only while eating)	CIII
Clean dentures twice daily when not wearing them, in antimicrobial denture soaking solution	BIII
Prevention of IV Catheter Infection	
HSCT centers should implement published CDC guidelines for prevention of intravascular catheter-associated infections	AIII
Tunneled or nontunneled central venous catheters should be inserted using maximal sterile barrier precautions	AI
Contact with tap water at the central venous catheter site should be avoided for devices that are not totally implantable	BIII
HSCT patients should cover the catheter tip during bathing and change catheter caps per manufacturers' recommendations	BII
HSCT recipients and caregivers should receive education regarding proper care of intravenous devices	AIII
Infection Prevention Surveillance	
HSCT centers should follow standard guidelines for surveillance of epidemiologically significant antimicrobial use, healthcare-associated pathogens, and susceptibility patterns	BIII
Routine fungal or bacterial cultures of asymptomatic HSCT recipients is not advised	DIII
In the absence of epidemiologic clusters of infections, routine surveillance environmental cultures are not recommended	DIII

Increased cases of invasive mold disease among HSCT recipients should trigger careful evaluation of the environment including the ventilation system	BIII
In the absence of an outbreak, routine fungal cultures of devices or dust need not be performed	DIII
HSCT centers should perform clinical surveillance for cases of invasive mold disease occurring among HSCT recipients	BIII
Adapted from the CDC/IDSA/ASBMT guideline.[6]	

PRETRANSPLANT EVALUATION

Before the transplantation, the patient should be evaluated for evidence of prior or ongoing infections. Serologic studies for CMV, EBV, HSV, and VZV should be considered. Other infectious diseases that may be evaluated include human immunodeficiency virus (HIV) I and II, Hepatitis B virus, Hepatitis C virus, human T-cell lymphotropic virus I, human T-cell lymphotropic virus II, *Treponema pallidum*, West Nile virus, and *Trypanosoma cruzi*.[6] Testing for tuberculosis should be considered for at-risk patients.[6] If possible, any necessary dental work should be completed.

INFECTION PREVENTION MEASURES

Routine infection prevention measures that should be applied to HSCT patients include scrupulous attention to aseptic technique in the care of intravascular catheters,[82,83] (see **34. Intravascular Device Infection** regarding recommendations to prevent catheter-associated infections) and routine infection prevention measures in the care of urinary catheters, wounds, tracheostomy sites, and in the disinfection of respiratory therapy equipment (see **67. Respiratory Care Services** for disinfection recommendations for respiratory therapy equipment).

Unfortunately, surrogate markers to measure the relative risk of individual patients accurately are not available. Most of the specific recommendations for infection prevention in HSCT patients are based on a common-sense approach to these uniquely immunosuppressed patients, rather than precise data. Very few infection prevention practices have been tested in a prospective, randomized fashion. A few specific areas of particular concern follow.

Inanimate Environment

Guidelines for environmental infection prevention should be implemented.[84] Furnishings and fixtures in patients' rooms should be easy to clean. Items that collect or trap dust should be avoided. Well-trained, reliable staff should be selected to clean rooms. Sterile linen, dishes, and utensils are unnecessary.

Food and Nutrition/Flowers

The potential benefit of food safety recommendations must be weighed against the potential to adversely affect nutrition intake and/or quality of life. HSCT recipients' diet should be restricted prior to engraftment to decrease the risk for exposure to food-borne infections relating to bacteria, yeasts, molds, viruses, and parasites. Consumption of fresh fruits and vegetables, including raw vegetable sprouts, that cannot be effectively washed or peeled should be restricted while patients are neutropenic because of potential for such foods to carry *Escherichia coli* and *Salmonella*. Flowers/plants or their potting materials may harbor large numbers of *Aspergillus* spores and should be restricted from the environment.[6]

Air

Because of the significant morbidity and mortality associated with infections due to *Aspergillus*, many transplant centers utilize special protective environments that have HEPA filtration. HEPA filters remove 99.97 percent of particles larger than 0.3 µm. Patient rooms should be sealed to prevent contamination from outdoor sources. Routine environmental sampling is generally not recommended, but air quality should be monitored, particularly during construction/renovation projects.[42] It is difficult to stipulate an acceptable level of fungal contamination of the air because low levels do not appear to correlate with fungal disease.[85] One center has related that HEPA-filtered areas should have less than 15 CFU/per m^3 total fungal spore counts and less than 0.1 CFU/per m^3 of *Aspergillus* spores.[86] Laminar airflow units are expensive and have not been shown to yield a clear survival benefit.[87, 88] In addition, with hospital length of stay being dramatically lowered because of the use of prophylactic regimens and colony-stimulating factors, the need for protective units is being re-examined. Clearly, great care should be exercised in planning and conducting hospital construction/renovation to avoid outbreaks of dust-borne aspergillosis (see). Prior to major construction projects, conduct an infection prevention risk assessment and educate personnel and construction workers on appropriate dust containment measures.[84]

Maintenance of the construction area at negative pressure, erecting impermeable dust barriers, and establishing controlled access to construction zones are some suggested measures to prevent construction-associated aspergillosis.

Water

HSCT patients are at increased risk of developing legionellosis. Measures that should be considered in the prevention of legionellosis include avoidance of water systems that allow water (particularly warm water) to stagnate and avoidance of plumbing fixtures or other devices that result in aerosolization of water (see **84. Legionella pneumophila**). Periodic cultures of the water supply are performed at some centers to detect *Legionella* spp. If *Legionella* spp. is recovered, the water supply should be decontaminated until the contamination is cleared. HSCT patients should not take showers with the water, and sterilized water should be used for drinking, brushing teeth, and flushing nasogastric tubes.[89]

Personnel and Visitors

Personnel should be required to practice scrupulous hand hygiene and strictly adhere to Standard Precautions in the care of HSCT patients.[90] All personnel in contact with HSCT patients should receive yearly influenza vaccination and should document immunity to VZV or receive varicella vaccine. Visitors should be screened for communicable diseases. Visitors with evidence of a respiratory tract infection or other communicable disease should be excluded from visitation.[6]

ANTIBIOTIC UTILIZATION

In an effort to prevent infection, patients are often placed on regimens of prophylactic antimicrobial agents. Prophylactic antibiotics decrease the risk of infection, but have been associated with the emergence of antimicrobial resistance. For example, penicillin-resistant *S. viridans* has been associated with the use of beta-lactam agents.[91] Infections due to quinolone-resistant coagulase-negative staphylococci and Gram-negative bacilli have been observed in centers using prophylactic fluoroquinolones.[92,93] As mentioned, prophylactic administration of fluconazole has been associated with an increased incidence of infections due to non-albicans *Candida* species, such as *C. krusei* and *C.*

glabrata.[31] More recently, the emergence of vancomycin-resistant enterococci has been associated with the overuse of vancomycin.[20] Other antibiotic-associated adverse events include *C. difficile*-associated colitis, which has been associated with the use of many antibiotics, particularly clindamycin, penicillins, and third-generation cephalosporins.[94] The use of anti-infectives for prophylaxis and empiric therapy should be balanced by considerations regarding resistance and toxicity.

PREVENTION OF INFECTION DUE TO RESPIRATORY VIRUSES

Common respiratory viruses such as influenza and RSV can cause devastating disease in HSCT recipients. In addition, they are very common among the general population during the respiratory infection season. The CDC recommends measures to prevent infection by these organisms.[89,95] The CDC guidelines for prevention of healthcare-associated pneumonia should be implemented.[96] Patients with respiratory syndromes should be placed in appropriate infection prevention precautions to prevent transmission to HSCT recipients. Appropriate protective equipment (such as gowns, masks, goggles) should be used in the care of patients with respiratory infections when coming into contact with potentially infectious respiratory secretions or contaminated objects. Protective equipment and clothing should be changed at appropriate intervals. Visitors and HCP should be screened for respiratory infections, and those with upper respiratory infection symptoms should be restricted from contact with HSCT patients. HSCT patients with signs or symptoms of respiratory virus infection should have appropriate diagnostic tests of respiratory secretions performed promptly so that appropriate therapy can be initiated. It should be noted that viral shedding can be prolonged in HSCT patients with a respiratory infection, and precautions may need to be continued for a prolonged period. Diagnostic tests (i.e., culture, antigen detection) can be used to guide the need for Transmission-Based Precautions.

IMMUNIZATION OF TRANSPLANT RECIPIENTS

Antibodies to various vaccine preventable diseases decrease following HSCT. To prevent these diseases, patients should routinely be revaccinated following HSCT. The vaccines discussed in the following paragraphs are recommended for both autologous and allogeneic HSCT recipients, regardless of the cell source.[6]

Diphtheria/Tetanus/Pertussis

Diptheria, tetanus, and acellular pertussis (DTaP) is preferred for all HSCT recipients. If DTaP is unavailable, tetanus, reduced-dose diphtheria and reduced-dose pertussis vaccine (Tdap) may be used. Vaccinations should be given at 9 months, 12 months, and 15 months following HSCT. Children younger than 7 years of age should receive a fourth dose of DTaP 18 months following HSCT. Children over age 7 and adults should receive Tdap 18 months following HSCT.[6]

Haemophilus influenzae type B

*Haemophilus influenzae*type B conjugate vaccine should be administered at 12 months, 15 months, and 18 months following HSCT.[6]

Hepatitis B

Hepatitis B vaccine should be administered at 12 months, 15 months, and 18 months following HSCT.[6]

Influenza

Seasonal administration of inactivated influenza vaccine is indicated for all HSCT patients age 6 months and older (regardless of immunosuppression), starting 6 months after HSCT. For HSCT patients less than 9 years of age who are receiving the influenza vaccine for the first time, two doses should be administered, approximately 1 month apart.[6]

Pneumococcal

Pneumococcal conjugate vaccine (PCV) should be administered at 6 months, 9 months, and 12 months following HSCT. The fourth dose should be administered at 18 months following HSCT. This dose may be either a conjugate or polysaccharide vaccine. If the patient is off immunosuppression, the polysaccharide vaccine may be used to broaden the immune response. For patients on immunosuppression, the PCV vaccine should be used as they are less likely to respond to the polysaccharide vaccine.[97]

Polio

Inactivated polio vaccine is indicated at 9 months, 12 months, and 15 months following HSCT.[6]

Measles/Mumps/Rubella

Vaccination for measles, mumps, and rubella should be given 24 months after HSCT to all children and seronegative adults. Children should receive a second dose in 3 to 6 months.[6]

Human Papillomavirus

Vaccination for human papillomavirus may be considered based on current vaccination guidelines for the general public. No data exist on when to initiate vaccination.[6]

Meningococcal Disease

Vaccination for meningococcal disease using a conjugate vaccine may be considered based on current vaccination guidelines for the general public. Vaccination may be initiated 6 to 12 months following HSCT.[6]

Varicella

Varicella vaccine may be considered for patients who are at least 24 months posttransplant, are not receiving any immunosuppressive medications, and do not have any evidence of active GVHD. Zoster (shingles) vaccine is not recommended.[6]

Tuberculosis

Bacillus Calmette–Guérin vaccination is contraindicated in HSCT recipients.[6]

Other Vaccinations

Hepatitis A and rabies vaccine are not routinely recommended. HSCT patients traveling to areas where yellow fever, Japanese B encephalitis, and tick-borne encephalitis are endemic should be evaluated on a

case-by-case basis considering the risk-benefit of vaccination. No recommendations exist for the timing of these vaccines.[6]

LONG-TERM PRACTICES

Following successful HSCT, recipients should adhere to strategies to avoid infection.[6] Good hand hygiene and respiratory hygiene practices should be encouraged. HSCT recipients should also avoid inoculation of potential pathogens by not touching their mucous membranes. Contact with persons with respiratory illnesses should be minimized, and HSCT recipients should avoid crowded public areas, particularly during respiratory infection season. Certain activities and occupations (e.g., working in homeless shelters or prisons, farming, and ranching) can increase the risk of exposure to a variety of infectious agents, and these issues should be considered in the decision to initiate or continue such activities. To prevent fungal infections, certain environments (construction sites, bird roosts, caves) should be avoided for 6 months after HSCT and during periods of immunosuppression. Some authorities recommend that HSCT recipients wear gloves and avoid creation of plant or soil aerosols while gardening. HSCT recipients not in long-term, monogamous relationships should use condoms during sexual contact and avoid sexual practices that could result in oral-fecal transmission. Pet or animal exposure can result in transmission of infection. Generally, HSCT recipients are not advised to part with their pets but are counseled regarding potential risks. Pet owners should be vigilant regarding their pet's health and avoid acquisition of pet-associated diseases. HSCT recipients should practice dietary discretion and avoid food and drink that has a high likelihood of harboring pathogens (such as unpasteurized dairy products, raw eggs, raw or poorly cooked meat, and poorly monitored well water). Travel may pose unique risks to HSCT recipients, and they are advised to consult their physicians well before embarking on travel to developing countries.[6]

Conclusions

Despite the development of new vaccines and more effective antimicrobial agents, infectious agents continue to cause significant morbidity and mortality in highly susceptible HSCT patients. Specific measures should be taken in both the pre-transplant and posttransplant period to limit the exposure to potentially pathogenic microbes and prevent reactivation of latent infection. Stringent adherence to infection prevention practices is vital to protect HSCT patients from preventable infections. Future work should be directed at better defining the most effective preventative measures, with an emphasis on delineating costs and outcomes.

Supplemental Resources

American Society for Blood and Marrow Transplantation (ASBMT). Available at: **http://www.asbmt.org**.

Center for International Blood and Marrow Transplant Research (CIBMTR). Available at: **http://www.cibmtr.org**.

Centers for Disease Control and Prevention (CDC). Available at: **http://www.cdc.gov**.

National Cancer Institute (NCI). Available at: **http://www.cancer.gov**.

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Nutrition and Immune Function

Author(s): Karen S. Geismar, MS, RD, LD, CNSC
Lecturer, Department of Nutrition and Food Sciences

Texas A&M University
College Station, TX

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Abstract

The role of nutrition in hospital recovery cannot be stated too strongly. Nutrition plays a premier role in a strong response system to the ravages of infection on the body. The immune system, which is the body's defense mechanism against infection, relies intricately on how well the body is nourished. Marginal nutritional status leaves a person more susceptible to infections and less able to fight off any foreign invaders. Malnutrition is the result of inadequate or excess protein, calories, and/or micronutrients, which may be indicated by abnormal blood chemistries, loss of lean body mass or gain of adipose tissue, and/or impaired organ function.[1,2] If left untreated, malnutrition can lead to increased morbidity and mortality. Undernutrition may be characterized by deteriorated functional ability and poorer clinical outcomes that usually occur when weight loss exceeds 10 to 20 percent of pre-illness body weight. Overnutrition is associated with increased risk of chronic conditions and altered immune function.[3,4] Despite the most advanced laboratory and assessment tools available for nutritional assessment, there is no single test that is both sensitive and specific for malnutrition.[5] Diet and weight history and physical exam for loss of lean body mass may be a more sensitive indicator. Malnourished medical and surgical patients have more complications (e.g., slower healing, increased incidence of infection, and multiple organ failure) than do those who are well nourished. Consequently, they have longer hospital stays and increased mortality rates, and they incur higher medical costs. Medical nutritional therapy must be considered along with drug interventions in the patient care plan for recovery from the infection process.

Key Concepts

- Malnutrition may be a result of inadequate or excess nutrient intake.
- Malnutrition alters the body's ability to prevent and/or combat infection.

- The consequences of infection include the risk of developing malnutrition.
- Eating patterns can deteriorate nutritional status, which leaves a person more vulnerable to the inflammatory and infectious process.

Background

Malnutrition is defined as an imbalance of nutrient intake or stores compared to physiological requirements.[6] This imbalance may be brought on by reduced macronutrient or micronutrient intake or absorption or impaired nutrient utilization. The classic picture of malnutrition is the marasmus or wasting associated with chronic inadequate intake of energy and other nutrients. However, the face of malnutrition has transitioned since the 1980s to that of an overweight or obese population, apparent in the United States and globally.[7] Both undernutrition and overnutrition can alter immune response and health outcomes.

Worldwide, an estimated 842 million people do not have access to adequate, nutritious food, increasing their risk of developing undernutrition.[8] The negative effects and health outcomes associated with undernutrition are well documented. The face of malnutrition is often associated with wasting due to chronic inadequate intake of energy and protein, known as undernutrition. Those who are undernourished have a higher incidence of infection, reduced quality of life, impaired ability to heal, and greater risk of mortality. Undernutrition is associated with chronic reduced intake of macronutrients and/or micronutrients; however, increased losses or requirements brought on by illness may also drive undernutrition. Although this condition may be thought to be isolated to developing countries, this problem is also found in industrialized countries, particularly in hospitals, long-term care facilities, and clinics that treat those with acute or chronic diseases.[9]

Alternatively, overnutrition, often defined as overweight or obese status, is associated with increased risk of chronic health conditions, increased healthcare costs, and altered immune response.[4,10] In the United States, the annual healthcare cost for those who are obese is nearly $1,500 greater than for those who are not.[7] This condition tends to be more prevalent as developing countries become more economically prosperous and is associated with more plentiful, less expensive food that tends to be more energy dense.[11] The etiology of obesity is complicated, but can be summarized as energy intake that is greater than energy expenditure, resulting in excess deposition of adipose tissue. It must be emphasized that this excess fat store does not always correlate with excess micronutrient stores. In fact, micronutrient deficiencies may be greater in obese populations than in persons whose weight status is normal.[12]

The effect of nutrients and nutrition status on immune function is complex and not always well understood. Although some individual nutrients are directly involved with the immune system, provision of other nutrients and food components may assist in modulating or assisting the immune response. This chapter will attempt to provide an overview of many of these interactions.

General Effects Of Malnutrition On Immune Function And Infection

UNDERNUTRITION

Risk of undernutrition is associated with inadequate access to nutritious foods or increased nutrient requirements that are not met via diet, also known as protein-energy malnutrition (PEM). Individuals at risk for malnutrition include children, pregnant women, elderly persons, and those who are ill.[13] Illness may be defined as acute or chronic, both of which may be associated with increased nutrient requirement, impaired nutrient absorption, altered nutrient utilization, and increased nutrient losses.[5]

Therefore, ill and hospitalized patients are considered to be at risk for undernutrition. This may develop in the hospital even if a patient was admitted with normal to marginal nutritional status. Conditions such as trauma, sepsis, and major surgery are associated with increased risk for malnutrition, even in a previously well-nourished individual. Acute illness may increase the release of counter-regulatory hormones and cytokines whose function is to mobilize nutrient stores for repair or recovery. If not corrected, this may result in rapid decline of nutrition status. Recovery may be impaired if nutrition status declines. Anabolism is difficult to attain until the response to illness subsides.[14]

Impact of Undernutrition on Immune Function

The impact of undernutrition and nutrient deficiencies on immune function is well documented. Cell-mediated immunity is most significantly altered; however, humoral response, phagocytosis, and complement are also affected.[15,16] A decline in immune response occurs late in simple starvation (marasmus) as the body adapts to conserve lean body mass (protein stores). However, immunosuppression can develop rapidly into protein malnutrition or malnutrition complicated by critical illness/infection.[17] This undernutrition can lead to a wasting of the body, cachexia, which is commonly seen in patients with cancer and is reported to affect 85 percent in some types of cancer.[1]

Clinical signs of impaired immunity may be subtle or difficult to interpret. Anergic response to delayed cutaneous hypersensitivity skin testing and total lymphocyte count less than 1,500/mm^3 have been used to evaluate immunosuppression from undernutrition. However, in the acute care setting these are generally not useful, because the results are affected by many non-nutritional factors (e.g., infection, surgery, numerous disease states, and medications).[18] PEM or specific nutrient deficiency predisposes the individual to increased incidence and/or severity of infection in most instances.[2] Examples include most bacterial infections (including tuberculosis and diarrheas from *Escherichia coli [E. coli]* or *Shigella*); many viruses (e.g., rota-virus, measles); and some fungi and systemic parasitic infections (e.g., *Entamoeba histolytica*).[2,19]

Impact of Overnutrition

Approximately one-third of the population in the United States is classified as obese, a trend that has increased since the 1980s.[7] This epidemic is not isolated to the United States; since 1980, the rate of obesity worldwide has nearly doubled, with an estimate of 500 million classified as obese.[10] Although undernutrition is still a nutritional concern, particularly in developing countries, overnutrition or obesity impacts morbidity and mortality rates as well. Recent evidence indicates that obesity may also alter immune function and increase the risk of infection, hindering recovery.[3]

The health impact of obesity is commonly focused on the increased risk of certain chronic conditions, such as cardiovascular disease, type 2 diabetes, some forms of cancer, and nonalcoholic fatty liver

disease.[4,20] Innate and adaptive immune functions appear to be affected by obesity and possibly linked to the adipokines derived from the adipose tissue such as leptin and adiponectin.[3,4] Obese individuals are found to have a chronic but low degree of inflammation, as evidenced by increased levels of inflammatory markers, such as tumor necrosis factor-α (TNF-α), C-reactive protein (CRP), and interleukin-6 (IL-6).[4] Leptin appears to influence this inflammation via the activation of pro-inflammatory T-helper cytokine production, creating an imbalance of pro-inflammatory to anti-inflammatory milieu. Research in mice and humans suggest obesity-associated inflammation is directly tied to this pathogenesis of chronic conditions.

There appears to be an increased risk of acute illness in those who are obese compared to those who are normal weight. Epidemiological data indicate that obese individuals are more likely to be impacted by infection compared to normal-weight subjects.[3] Those in the hospital setting have a higher rate of infection, increased length of hospital stay, and greater risk of mortality. Unfortunately, the pathophysiology of these immunological dysfunctions is not fully understood. Although specific immunological alterations have been identified both from human and animal studies (see Table 47-1), the exact mechanism of this altered response is not fully elucidated, making an intervention difficult to develop.

Table 47-1. Alterations of Immune Function in Obesity[3,20,21,22]

Table 47-1 Alterations of Immune Function in Obesity

Impaired lymphocyte proliferation
Enhanced thymic aging
Reduced T-cell diversity
Increased activation of toll-like receptor-4 via free fatty acids
Increased levels of IL-6, TNF-α, CRP
Suppressed immune response to hepatitis B, tetanus, and influenza vaccines
Increased macrophage infiltration in adipocytes

Logically, the long-term solution is to encourage weight loss, but it is uncertain that weight loss is beneficial in the acutely ill, obese population. In the critically ill, obese population, nutrition support methodologies have been implemented that may positively impact the patient outcomes.[23] The topic of hypocaloric feeding in obese persons is discussed in the nutrition support section of this chapter.

Altered immune response to specific vaccinations is also noted in obesity.[3,21] During the 2009 H1N1 flu pandemic, obesity was found to be a significant risk factor for morbidity and mortality due to influenza. Although initial immunoglobulin G antibody levels were found to be elevated postvaccination in obese subjects, titers measured at 12 months postvaccination indicated that titer levels declined to suboptimal levels. The drop of titer levels appeared to be negatively correlated to degree of obesity. The potential mechanism of this impaired immune response to the vaccination may be due to the reduced activation of CD8 T cells. Antibody response is also reduced with Hepatitis B and possibly tetanus vaccine.[3,21,22]

Diagnosis of Malnutrition/Undernutrition

Although the term "malnutrition" may apply to either undernutrition or overnutrition, in the clinical setting it is commonly used to describe those who are undernourished. In the hospitalized patient, the diagnosis of malnutrition or undernutrition has historically been based on laboratory data, specifically visceral proteins such as albumin and prealbumin. However, these are negative acute-phase visceral proteins that decline during the acute phase response, thus they are unreliable indicators of altered nutrition status.[5,14] Furthermore, these visceral proteins may not decline during uncomplicated starvation, such as anorexia nervosa, severe calorie-restricted diets, and other conditions of starvation.[5,24,25] Nonlaboratory variables that may more reliably predict malnutrition include history of suboptimal dietary intake; unintentional weight loss; physical exam that indicates a loss of fat or muscle mass; and reduced functional status as measured by a reduced hand-grip strength.[5] A thorough assessment by a registered dietitian can assist in assessing for this condition.

The assessment of overnutrition or obesity is generally done using body mass index (BMI), a measure of kilogram of body weight divided by the height in meters, squared.[26] BMI is now the preferred method to diagnose overweight or obese individuals.[27] A BMI of 25 to 29.9 kg/m^2 is considered overweight, whereas a BMI of 30 or more kg/m^2 is considered obese. A more appropriate BMI for elderly persons may be between 25 and 27 kg/m^2.[26] Clinical judgment is necessary to determine if the individual is overweight or obese due to excess fat stores versus excess muscle mass. BMI is not a valid screening tool for those with amputations, ascites, or edema.[27] An edema-free weight may be used to calculate BMI if available. Body fat estimates such as skin-fold measurements are not routinely used in the clinical setting. Although BMI is strongly correlated to excess fat stores and risk of metabolic complications, the deposit of fat in the abdominal regions is also a risk factor. Immune dysfunction may be linked to visceral fat.[28]

General Effects of Infection on Nutrition Status

Infection may worsen nutritional status by increasing metabolic demands or decreasing intake and absorption. The clinical significance depends on the duration, severity, and type of infection.

Illness is associated with hypermetabolism and a rise in energy expenditure. The rise in energy expenditure may correspond to the degree of illness or metabolic stress; however, it is important to note that this hypermetabolism is variable and may be difficult to predict due to patient treatment.[29] For example, fever, if present, will increase caloric needs approximately 10 percent for each degree centigrade above normal, but in clinical settings fever may be treated and thus negate this rise in thermogenesis. Furthermore, hypermetabolism may be offset to some extent by a decrease in physical activity.[29]

Protein stores may also be altered during acute illness. Protein loss due to wounds, gastrointestinal exudate, or immobilization of stores due to stress may deplete nutrient stores.[14,17] During severe catabolic illness, negative nitrogen balance is generally present despite a provision of adequate calories and protein and may not improve until the acute event has resolved. Sparing protein (i.e., lean body mass) is a primary goal of nutrition support during critical illness.[14]

Infection and illness alter the nutritional status of the affected individual by decreased nutrient intake. This occurs due to anorexia, nausea, and/or vomiting directly associated with the infection. Treatment of infection via medications may alter the taste of food or reduce appetite. Lack of appetite may also be cytokine-driven, as in the case of cancer cachexia, and may be associated with loss of lean body mass.[30] Other causes of reduced intake may be altered smell, food aversions, early satiety, nausea, and apathy. Investigation of the cause of reduced intake is imperative for effective treatment.

A wide variety of infections can result in malabsorption. Mechanisms include diarrhea (from enteric pathogens such as *E. coli, Shigella*, and *Giardia lamblia*); reduction of the mesenteric blood flow (e.g., malaria); or physical blockages or damage to intestinal surfaces (which occur with severe worm burdens or tropical enteritis, respectively).[31] Specific nutrient deficiencies can also occur secondary to infection.

Iron losses can be significant from hookworm. Megaloblastic anemia can result from competition of *Diphyllobothrium latum* for host vitamin B12. Folate may also be poorly absorbed. Increased requirements or losses through urine or malabsorption can also precipitate symptomatic vitamin/mineral deficiencies when host stores are marginal. Deficiency of vitamins A, C, B12, thiamin, and niacin have been noted during infection as a result of increased requirements or losses through urine or malabsorption.

The Effect of Specific Nutrients on Immune Function

The association between nutrition or nutrients and immune function is complex and difficult to concisely summarize. Dietary provision of energy, protein, and micronutrients may work synergistically to support and modulate the immune response. Dietary components can positively affect immune function by correcting a deficiency or producing a pharmacologic effect. An evaluation of altered immune function resulting from single nutrient deficiency is challenging, because isolated states of protein, calorie, vitamin, or mineral deficiency are rare in humans (with the possible exception of iron, zinc, or vitamin A).[32] Biochemical measurement of some nutrient levels may be altered by disease status, further confounding definitive diagnosis of deficiency.[33,34]

The link between individual nutrients and disease is a growing field of research. Early animal research indicated that a benign coxsackievirus can evolve into a virulent form in a host that is deficient in selenium or vitamin E.[35] This was the first example of host antioxidant status possibly altering genetic sequence of a virus, thereby enhancing its virulence. Subsequent research indicates that selenium and vitamin E status may enhance viral mutation and pathogenicity.[36] However, some viral and parasitic infections (e.g., malaria) may be less severe in the malnourished patient, because these microorganisms compete for limited host nutrients.[37] Still others, such as yellow fever or poliomyelitis, appear not to be influenced by malnutrition.[38]

A few infections can be made worse by nutrient repletion. Aggressive refeeding of a malnourished patient with tuberculosis can result in an exacerbated infection, especially if no antitubercular medication is provided.[37] Iron supplementation may enhance the proliferation of some microorganisms.[39] Controversy exists regarding the benefits of providing iron to malnourished patients with an iron-deficiency anemia.

CALORIES

The components of total energy expenditure (TEE) include basal metabolic rate (BMR), thermic effect of food, physical activity, growth, and illness.[29] Of these components, basal metabolic rate accounts for the largest portion of TEE and is generally proportional to body size and degree of lean body mass. Other factors that may affect BMR include gender, temperature, climate, and stimulants.[40] Starvation reduces BMR as part of the adaptive process in order to conserve fuel stores, making accurate assessment of TEE difficult in this population.[41] Illness may alter energy expenditure; illness and inflammation elevate BMR, but the degree of elevation does not seem to be as extreme as early studies on energy expenditure in the critically ill indicated.[29] Although considered the gold standard, the measurement of energy expenditure via direct and indirect calorimetry is often costly and inaccessible unless working in a research institution. Predictive energy equations are available to estimate energy needs in the healthy and ill population and are discussed elsewhere.[42,43,44]

A minimum kilocalorie (kcal) intake is essential for maintenance of bodily processes. Prolonged inadequate intake relative to energy needs is often accompanied by inadequate protein and micronutrient intake. An undernourished individual may exhibit a decreased ability to fight off infections, Recent weight loss appears to have a more detrimental effect on nutrition status than a gradual decline in weight over time.[5] Taking a weight history that includes periods of weight loss, a patient's lowest and highest weight in his/her adult years, and a person's history of dieting are helpful in establishing some baseline information on kilocalorie intake.

Interviewing the patient will assist with collection of a detailed diet history. This information is useful for estimating kcal and protein intake. Inquiry of eating patterns and food frequency may provide additional information regarding micronutrient intake. A written diet history by the patient or a family member that prompts for information on serving sizes and mood may provide further assistance in developing the appropriate intervention. Table 47-2 provides an example of a dietary intake tool. Although typically used for weight-loss interventions, the food recall can also provide information on nutrient status.

Table 47-2 Example of Food Diary

Please fill out the following form as best as you can recall showing your food choices on a typical weekday and weekend day.

Day of week:________

Time of day	Food eaten	Amount	Mood when eating

PROTEIN

Protein is necessary for the production of new tissue and repair of existing tissue. Building blocks of protein are amino acids, and although 11 of these 20 amino acids can be synthesized in the body, 9 are absolutely essential for maintenance and repair of body tissues.[45,46,47] Others that are generally nonessential may become essential during times when requirements must be met rapidly, such as acute illness or injury. These amino acids are known as conditionally essential. Antibodies, produced by white blood cells, are composed of protein. With insufficient protein, there is an inadequate immune system.[19]

The recommended dietary allowance (RDA) for protein for adults is 0.8 g per kilogram of body weight.[48] Amino acids are not stored in the body but are converted to fat and/or glucose stores after immediate protein needs are met.[49] Thus, it is essential that protein is regularly consumed. Sources of dietary protein include animal or plant sources as long as all nine of the essential amino acids are consumed. If a patient is vegetarian, plant sources will suffice if there are a variety of foods chosen. It is not necessary for a person to consume or complement proteins at each meal. The body will balance out amino acid needs if there is regular intake of the essential amino acids.

During stages of acute illness, the body may go into a state of negative nitrogen balance, where more protein is lost from the body than is retained, and this can be detrimental to the recovery phase. The degree of nitrogen loss may be directly proportional to the degree of acute illness.[50,51] The body needs to be in a state of positive nitrogen balance so as to enhance recovery. This is a stage where more protein is held in the body than is excreted.

VITAMIN C (ASCORBIC ACID)

Vitamin C or ascorbic acid is considered necessary for wound healing and is believed to be essential for a strong immune system.[52] Vitamin C also functions in enhancing leukocyte function to support the immune response.[53] The vitamin serves as a cofactor in the hydroxylation of proline and lysine in the synthesis of collagen and other components of tissues. Vitamin C regenerates vitamin E to an

antioxidant form and preserves its antioxidant functionality.[54] Vitamin C deficiency manifests with symptoms associated with scurvy, including bruising, petechia, slow recovery from fractures and wounds, and easy bleeding.[53] Furthermore, with its role in supporting the immune system, impaired response to infection may also result.

The role of vitamin C in support of immune function is not only associated with its proliferative effects and for its antioxidant abilities. Vitamin C directly stimulates neutrophil and monocyte activity.[55] As an antioxidant, vitamin C protects neutrophils from damage caused by reactive oxygen species. Research on vitamin C and immune function included work by Linus Pauling, who investigated the relationship between a high dose of the vitamin (greater than 1 gram/day) and reduced incidence of the common cold.[56] Outcomes of this research and subsequent studies found no benefit from vitamin C in the prevention of the common cold, though the duration of cold symptoms may decline. Furthermore, some studies suggest that there may be a benefit for vitamin C supplementation in those under physiological stress, such as those who exercise at an intense level (i.e., marathon runners). These athletes may have a reduced incidence of upper respiratory infections following exercise of long duration. This finding, though, has not been supported by all studies.[52] Immunological markers may be elevated after supplementation of vitamin C, but more data are needed on the health outcomes associated with these increases.[55]

Because of its role as an antioxidant and in collagen synthesis, vitamin C supplementation has long been believed to be beneficial in the promotion of wound healing for pressure ulcers and surgical wounds.[57] Supplementation may only be indicated in those who are or are suspected to be vitamin C deficient, as data are inconclusive on the benefits for those with adequate vitamin C status. Further discussion of nutrition intervention for pressure ulcers and wounds is discussed in this chapter.

Vitamin C absorption in the small intestine will vary with the dose, with absorption as low as 16 percent at high intakes (up to 12 grams) and as high as 98 percent with low intakes (as low as 12 mg).[53] The unabsorbed vitamin remains in the intestinal tract and may be fermented by the intestinal bacteria, inducing an osmotic diarrhea. The recommended dietary allowance (RDA) for vitamin C is 75 to 90 mg per day.[58] Dietary sources of vitamin C include fruits and vegetables, particularly citrus fruits (Table 47-3). Because smoking results in depletion of vitamin C, smokers are recommended to consume an additional 35 mg of vitamin C.[53] Others at risk for low vitamin C status include elderly persons, those who abuse alcohol or drugs, and those with documented poor diets. Non-Hispanic, black males in the United States may also be at risk for deficiency.[59] Toxicity of vitamin C is generally associated with the gastrointestinal side effects, though individuals at risk for kidney stones and those with disorders of iron metabolism should be cautious about consuming large amounts of this vitamin.[53] Furthermore, those with end-stage chronic kidney disease are at risk for oxalosis and should limit their intake to no more than 100 mg per day.[60]

Table 47-3. Dietary Sources of Vitamin C[53,54]

Table 47-3 Dietary Sources of Vitamin C

Fruits

Oranges
Grapefruit
Cantaloupe
Strawberries
Kiwi
Papaya
Vegetables
Bell peppers
Broccoli
Brussels sprouts
Potatoes

ZINC

Zinc is needed for cellular growth, replication, and differentiation; it promotes wound healing and ensures adequate immune response.[61] It is required as a cofactor for as many as 200 enzymes, including superoxide dismutase. The benefits of zinc supplementation on wound healing of surgical wounds and pressure ulcers and immune function are inconclusive. Zinc supplementation has been shown to be beneficial in wound healing in a number of studies; however, the benefit appears to be limited to those who are zinc deficient.[57,62] Furthermore, zinc supplementation in the treatment of pressure ulcers does not appear to be beneficial.[57] Immunological benefits of zinc supplementation are also conflicting. Zinc supplementation from lozenges or nasal spray in reducing the duration or symptoms of the common cold has been studied.[55]

Although animal foods are the prime sources of dietary zinc, plant foods provide significant amounts of this mineral (Table 47-4). It is difficult to absorb zinc from some plants that contain phytic acid, which competes with zinc for absorption. The RDA for zinc is 11 mg/day for men and 8 mg/day for women.[58] Patients at increased risk of zinc deficiency include those with decreased intake (e.g., unsupplemented total parenteral nutrition or vegans) or increased gastrointestinal losses from copious diarrhea/fistula output.[61,62] Signs and symptoms of zinc deficiency include poor wound healing, increased rates of infection, altered taste, skin rash or dermatitis, and diarrhea. Low zinc status in elderly persons may be associated with increased risk of pneumonia.[63] This population, as well as those with persistent diarrhea, may benefit from zinc supplementation. Zinc supplementation in children with diarrhea assists with the reduced frequency and duration of stool output, though the exact mechanism for this benefit is not understood.[64,65] Zinc is needed for the transport of vitamin A in the blood; therefore, a zinc deficiency may also lead to secondary vitamin A deficiency.[61] Serum levels of zinc are not believed to be accurate predictors of zinc status.[62] The tolerable upper intake level for zinc is 40 mg/day.[58] Toxicity of zinc is also associated with negative effects on wound healing, as well as increased risk for infection.[61,62] Excess

zinc supplementation may reduce the bioavailability of copper and iron, thus increasing the risk of deficiencies.

Table 47-4. Dietary Sources of Zinc[61,66]

Table 47-4 Dietary Sources of Zinc

Animal Sources
Oysters
Crabmeat
Beef
Veal
Pork
Chicken
Cheese
Eggs
Yogurt
Plant-based Sources
Legumes
Bread
Rice and pasta
Vegetables

VITAMIN A

Vitamin A is needed for cellular differentiation to maintain cellular integrity. The epithelial cells of the skin and intestinal tract are primarily involved in immune function and are simultaneously dependent on vitamin A.[67]Vitamin A and retinoic acid may be involved in T-cell regulation and differentiation, which encourages balance of inflammatory processes, thus maintaining gut homeostasis. Epithelial cells play a major role in intestinal bacterial infections and infections overall.[67,68]For example, mucus is secreted by some epithelial cells to protect the mucosa; these cells require a regular dose of vitamin A to perform their functions. Vitamin A deficiency results in a decrease in mucus production in these cells, as well as cells in the intestines and lungs.

The RDA for vitamin A for adults is 700 μg retinoic acid equivalent (RAE) for women and 900 μg per day for men.[58]Supplement labeling does continue to use international units (IU) for vitamin A. One IU is equivalent to 0.3 μg of retinol. Requirements increase during pregnancy and lactation. Night blindness and xerophthalmia may develop with vitamin A deficiency; night blindness is reversible with supplementation, whereas xerophthalmia results in permanent loss of vision. Although vitamin A deficiencies are somewhat rare in the United States, internationally it is the cause of blindness in

approximately 250 million children.[69] Fifty percent of these children will die within 1 year from subsequent infections that follow a severe vitamin A deficiency. Vitamin A deficiency in pregnant women in developing countries may increase the risk of maternal mortality.[70] A deficiency of vitamin A affects immune function by allowing for increased T-helper type 1 proliferation, which leads to production of pro-inflammatory cytokines.[67,68] Overall, there is a decreased function of the immune system and subsequently an increase in the number of infections. This inflammation has been tied to the increased risk of chronic conditions associated with obesity.[68] Groups at risk for a vitamin A deficiency are listed in Table 47-5.

Table 47-5. Groups at Risk for Vitamin A Deficiency[68,71,72]

Table 47-5 Groups at Risk for Vitamin A Deficiency

- Children, particularly in developing countries
- Patients with celiac disease
- Patients with liver disease
- Patients with pancreatic disorders
- Patients with cystic fibrosis
- Patients at risk for fat malabsorption
- Alcoholics
- Newborns and premature infants
- Elderly individuals
- Obese individuals
- Those on medications with reduced fat absorption (eg. cholestyramine, orlistat)

Vitamin A toxicity may occur with the intake of large amounts of vitamin A as retinol, and symptoms of vitamin A toxicity have been seen with intakes greater than 2,000 IU.[71] Retinol is teratogenic and may lead to birth defects if consumed in excess during pregnancy. Excess intake of vitamin A is also associated with increased risk of fractures and liver damage. The upper limit for vitamin A is 3,000 µg RAE per day.[58]

Dietary sources of vitamin A include animal- and plant-based foods. Animal sources contain retinoids, the active form of the vitamin.[71] Plant-based foods contain carotenoids, which may be converted to the active form of vitamin A as needed by the body. Dietary sources of vitamin A are shown in Table 47-6.

Table 47-6. Dietary Sources of Vitamin A[54,71]

Table 47-6 Dietary Sources of Vitamin A

Animal Sources

- Beef liver
- Chicken liver
- Whole-fat dairy products
- Eggs

Plant Sources

- Apricots
- Carrots
- Cantaloupe
- Mango
- Spinach
- Sweet potatoes

VITAMIN D

Vitamin D's function of maintaining serum calcium and phosphorus levels in the body and for bone health is fairly well documented and understood. Other functions of vitamin D in the body are a topic of many recent investigative studies. Pertaining to the topic of immune function, vitamin D has been found to be important in modulating the immune system, both the innate and adaptive immune responses.[73]

Initial research linking vitamin D to immune function involved vitamin D in the inhibition of *Mycobacterium tuberculosis*.[74] Vitamin D receptors are present on inactivated immunologic cells, a relatively recent discovery that further drove the research on this topic. The interaction between vitamin D and immune response is complex, but may be summarized as follows. Part of the response to injury includes macrophage proliferation to the injured site.[73,75] It is now known that macrophages are capable of activating vitamin D, as are dendritic cells. This activation appears to be stimulated by cytokine activity. Once activated, vitamin D will then inhibit T-cell proliferation and recruitment to the damaged site. Therefore, vitamin D appears to assist in stimulation of the innate immune response while modulating the adaptive.

Suboptimal levels or vitamin D deficiency are now linked to a number of chronic conditions, including type 1 and type 2 diabetes, hypertension and other cardiovascular disease, certain cancers, rheumatoid arthritis, and multiple sclerosis.[76,77] Other conditions associated with vitamin D deficiency include methicillin-resistant *Staphylococcus aureus,* healthcare-associated infections, and depression.[78,79,80]

Individuals who are at risk for vitamin D deficiency include those with inadequate sun exposure, including those who live above or below 40 degrees latitude; those with dark pigmentation; elderly persons; individuals living in nursing homes; and those wearing clothing that limits exposure to the sun.[53,76] Recent evidence suggests that there is a link between vitamin D deficiency and obesity; however, the evidence does not clearly identify if obesity is a cause of vitamin D deficiency or if the deficiency increases the risk for obesity.[81,82] The serum level 25-hydroxyvitamin D (25[OH]D) is considered to be an accurate measure of vitamin D status.[83] A serum level of 25(OH)D less than 30 ng/dL is believed to

indicate vitamin D deficiency. Serum 25(OH)D does not necessarily reflect the amount of vitamin D stored in body tissues, such as adipose tissue and muscle.[46,83,84]

The RDA for vitamin D was recently increased to 600 IU per day for those 70 years of age or younger and 800 IU per day for those older than 70 years of age.[58]The upper limit is now 4,000 IU per day.

Vitamin D toxicity from supplements may result in hypercalcemia and increased risk of calcification of soft tissues, such as the heart, kidney, and lungs.[71]Vitamin D is not found in large amounts in many foods. Fortified sources or sunshine may be an option. Dietary sources of vitamin D are found in Table 47-7.

Table 47-7. Dietary Sources of Vitamin D[47,64]

Table 47-7 Dietary Sources of Vitamin D

Milk
Margarine
Butter
Liver
Fatty fish (salmon, sardines, tuna, herring)

VITAMIN E

Vitamin E is a family of tocopherols, of which alpha-tocopherol serves as the active form of the vitamin in humans.[71]It is the major fat-soluble vitamin found in the skin. It acts as an antioxidant in the body, residing in cell membranes. Vitamin E is also a part of phagocytic cell membranes. Phagocytes generate a molecule called reactive oxygen species that can potentially damage the membrane of the phagocyte without antioxidants. Vitamins E and C serve to protect the phagocytes. Low vitamin E levels can diminish immune function in the body. A study showed that 200 mg/day of vitamin E improved the immune function of elderly persons, who in general have decreased immunity. Supplementation of vitamin E in elderly persons may reduce their risk of respiratory infections and influenza.[85,86]

The RDA for vitamin E is 15 mg/day for adults. It should be in the form of alpha-tocopherol, the most active form of vitamin E.[58]Good sources of this vitamin come from oils such as sunflower and canola oil. Breakfast cereals are often fortified with vitamin E. Other dietary sources of vitamin E are noted in Table 47-8. The upper limit for vitamin E is 1,500 IU for food sources of the vitamin and 1,100 IU for a synthetic vitamin.[58,71]Vitamin E toxicity may lead to hemorrhage.

Table 47-8. Dietary Sources of Vitamin E[54,71]

Table 47-8 Dietary Sources of Vitamin E

Wheat germ
Safflower oil
Soybean oil

Sunflower oil
Corn oil
Margarine
Eggs
Nuts and seeds (sunflower seeds, almonds, peanuts)

SELENIUM

Selenium, a trace mineral, plays a role in proper immune functioning. The RDA for selenium is 55 µg per day, and the upper limit is 400 µg per day.[58] Selenium deficiency has been associated with Keshan disease, a form of heart disease.[61,66] This was discovered when children with a form of heart disorder in the Keshan province of China were found to be deficient in selenium. Selenium is low in the soil in that Chinese province. Without selenium, the immune system cannot effectively fight the viral illness that affects the heart. Kashin-Beck disease is also associated with selenium deficiency.[87] This disease affects the cartilage and causes arthritis that can be deformative. A general symptom of deficiency is impaired immune response and a higher risk of viral infections. Selenium is found in both plants and animals.[61,66] The amount of selenium found in plants varies depending on the soil in which they were grown. Organ meats, nuts, rice, and wheat are good selenium sources.

Effects of Nutrition During Disease States

WOUND HEALING

Individual nutrients play a role synergistically with the others in keeping the body's defenses strong and promoting wound healing. Nutrition appears to play the most significant role in delaying wound healing if protein, calorie, vitamin A, vitamin C, or zinc deficiency is present.[53,57,61,62] However, other nutrients are also essential for healing, such as thiamin, riboflavin, pantothenic acid, iron, copper, and manganese.[62] The amino acids arginine and glutamine are also supplemented to enhance wound healing.

Pressure ulcers are a type of wound that is often associated with elderly persons in long-term care facilities. This population is at risk for malnutrition, and nutritional deficiencies are commonly present.[88] The risk of pressure ulcers may be increased in those with malnutrition and may be as high as 74 percent among elderly persons in acute or long-term care; therefore, prevention of malnutrition is considered an appropriate preventative measure. Although individual nutrients are important for appropriate wound closure, supplementation levels have not been established. Few studies on the supplementation of individual nutrients on wound healing show significant benefit for wound closure.[88,89] However, there may be some positive effect of supplementation of micronutrients with additional calories and protein in this population (i.e., medical meal replacement). Unfortunately, many of the studies suffer from small sample sizes, short-term duration of intervention, and/or lack of randomization. The National Pressure Ulcer Advisory Panel and European Pressure Ulcer Advisory Panel offer guidelines for nutrition care for those with pressure ulcers[57] (Table 47-9).

Table 47-9. Recommended Guidelines for Nutrition Care for Pressure Ulcers[57,58,61,90,91]

Table 47-9 Recommended Guidelines for Nutrition Care for Pressure Ulcers

Energy	30 to 35 kcal/kg body weight, adjust as needed in those with history of weight loss
Protein	1.25 to 1.5 g/kg body weight, per renal function
Fluid	No specific levels recommended. Monitor for appropriate hydration status.
Vitamins/Minerals	No specific levels. Encourage intake of nutrient-dense foods, such as fruits and vegetables. Supplement if deficiencies confirmed or suspected.
Vitamin C	No specific recommendations. RDA 75 mg/day for females, 90 mg/day for males Upper limit is 2,000 mg/day
Zinc	No specific recommendations. RDA 8 mg/day for females, 11 mg/day for males Upper limit is 40 mg/day. Excess intake may inhibit copper absorption, delay wound healing, and increase risk of infection.
Copper	No specific recommendations. RDA 900 µg/day for females and males Upper limit is 10,000 µg/day. Excess intake associated with GI distress, liver damage, and immune suppression.
Other dietary recommendations	Liberalization of diet if restrictions hindering adequate intake. Supplement foods to enhance nutrient intake or offer oral nutrition supplements. If intake suboptimal after nutrition intervention and if consistent with patient goals, consider nutrition support. Enteral nutrition support is the preferred method.

Vitamin A is an important micronutrient for the healing process, particularly related to its function of cellular differentiation. Vitamin A assists with maintaining normal structure and integrity of epithelial and mucosal cells.[53]Corticosteroids are known to impair wound healing, especially if given in moderate to high doses within a short period after injury. Vitamin A appears to prevent this deleterious effect of corticosteroids on wound healing, leading some clinicians to recommend supplementation with 10,000 to 15,000 IU orally per day to enhance wound healing in those on long-term corticosteroid use.

Other micronutrients commonly supplemented in wound healing include vitamin C and zinc. Vitamin C, as discussed previously, serves an important function in wound healing as a cofactor in collagen synthesis.[53,62]Supplementation is recommended in those who are or are suspected of being vitamin C deficient. The recommended dose of vitamin C supplementation to promote wound healing is 100 to 200 mg per day.[62]The benefit of zinc supplementation for wound healing is controversial and not consistently supported by data. As with vitamin C, zinc supplementation is apparently only beneficial in those who are zinc deficient. In this situation, the general recommended dose for zinc supplementation is 40 mg

elemental zinc per day for approximately 10 days. Since supplementation of zinc may interfere with the absorption of copper and iron, long-term supplementation is not recommended because of the concern for copper and iron deficiency.[61] Some data suggest that supplementation of vitamin C with zinc in the presence of adequate calories and protein may have some combined benefit on wound healing, but more research is needed to confirm this finding.[89]

The data are less clear on the benefits of individual nutrients for healing of wounds resulting from surgery or trauma in individuals who are well nourished. Currently, the data support the need for total nutrition intervention.[92,93] Studies in critically ill patients in the intensive care unit (ICU) have mixed results, possibly due to small sample sizes. Well-done studies on vitamin and mineral supplementation are lacking, but information that is available suggests that vitamin C and pantothenic acid may have some benefit.[89]

The wound healing effects of individual amino acids have also been found to affect immune function. Arginine is a nonessential amino acid that has been shown in studies to be essential for adequate immune function and wound repairs.[94,95] Arginine is considered an essential amino acid, and the level of plasma arginine has been noted to be low in those who are malnourished. Arginine assists with immune response by stimulating T-lymphocyte proliferation and macrophage response.[94,96] Glutamine, another amino acid, has been proposed to be important for wound healing and to support immune function. Glutamine is found in the skeletal muscle and may be immobilized during times of metabolic stress.[94] Glutamine is necessary for lymphocyte proliferation, antibody production, and modulates cytokine production. Glutamine is also a primary fuel for lymphocytes and enterocytes.[62] Larger and stronger studies are needed before definitive recommendations can be made on the use of these amino acids to enhance immune function. There is concern with supplementation of arginine during sepsis and it is not recommended that arginine be supplemented in those with severe sepsis and shock.[90] No established dose is available for arginine for wound healing; the accepted glutamine dose is 0.57 g/kg body weight/day.[62]

CLOSTRIDIUM DIFFICILE

According to the Centers for Disease Control and Prevention (CDC), *Clostridium difficile*(*C. diff*) infection (CDI) affects 337,000 people annually, killing approximately 14,000 of those infected each year.[97] It can be a healthcare-associated infection (HAI). Elderly persons are at greatest risk for CDI. Other risk factors include antibiotic therapy and hospital admission. New risk factors are emerging, including prolonged use of proton-pump inhibitors and presence of a gastrostomy or jejunostomy feeding tube.[91,97,98] Additionally, community-acquired CDI is becoming more common and may be affecting those not previously hospitalized. Medical management and practices to reduce transmission of CDI is discussed elsewhere in this book.

CDI pathophysiology is fairly well understood. The healthy normal intestinal flora serves as a barrier against colonization of *C. diff*.[98] Disturbance of the gut flora provides an opportunity for *C. diff* to colonize and produce toxins, which produce the classic symptoms of diarrhea. It would seem logical that the use of probiotics would protect against CDI. Probiotic species used in studies on the prevention of CDI include those in the following genera: *Lactobacillus, Bifidobacterium, Streptococcus,* and *Saccharomyces*.

[98,99]However, studies are mixed on the positive effect of probiotics for prevention of CDI, and results may be confounded due to small sample sizes and appropriate subject selection.[98,100]A meta-analysis and systematic review by Johnston et al. reported a significant risk reduction with the use of probiotics and reduced incidence of *C.diff*-associated diarrhea in patients receiving antibiotic therapy.[100]This review was based on the outcomes of 20 studies conducted on a variety of subjects that met their inclusion criteria. The authors report that the benefits may be greater with the use of multiple probiotic species, but this recommendation was made based on their analysis of the literature and not from an individual study. No adverse effects from the use of probiotics were reported in the studies reviewed. The only exception were reports of gastrointestinal symptoms (i.e., nausea, soft stools, taste changes) and fever. The authors did caution that their conclusions should be applied only to patients who were not immunocompromised or severely debilitated. Another systematic review determined that the promise of probiotic therapy for the prevention of CDI requires further investigation in robust and rigorous clinical trials.[101]The use of probiotics in critically ill patients remains uncertain and may be potentially harmful.[102]

The use of prebiotics on prevention of CDI appears to be in the preliminary phase. Intestinal bacteria ferment prebiotics, thereby enhancing their growth and improving the flora of the host.[103]Examples of prebiotics include soluble fibers and other nondigestible carbohydrates such as oligofructose saccharides. Research focused on the effects of prebiotics on the prevention of CDI are based on the theory that improved intestinal flora would inhibit *C.diff*colonization.[104]The few studies conducted to date have not shown benefit through this mechanism. Other potential mechanisms for inhibition of *C.diff*colonization are the prevention of epithelial adhesion of *C.diff*and other pathogens. An *in vitro*study indicates positive inhibition and may warrant further research.[105]

The Gut Microbiota

The human gastrointestinal tract serves as host to approximately 1,000 to 5,000 species of beneficial bacteria, also known as microbiota.[99]These bacteria interact or communicate with their environment—the host—to regulate processes in the body, particularly the immune system. Commensal bacteria reside within the mucus of the epithelial layer of the gastrointestinal tract and receive nourishment from this binding site and host diet and, in turn, can metabolize nutrients for the host.[106,107]The host diet, as well as genetics and environment, appears to influence the flora characteristics that may either positively or negatively affect host health. One pathway of this interaction is via a complex communication system that appears to regulate both innate and adaptive immune functions of the host. Depending on the characteristics of the commensal bacteria, this regulation may have positive or negative alterations of the host's health.[106]Beneficial bacteria may assist in combating infection and inflammation and maintaining homeostasis. However, if the microbiome is disrupted and the composition of the bacteria is altered, this homeostasis is also disrupted, and this may result in the development of inflammatory and metabolic conditions, such as obesity, metabolic syndrome, type 2 diabetes, and inflammatory bowel disease.[106,107]Common causes believed to disrupt the microbiome are antibiotics, diet, and malnutrition.[107,108]Other conditions linked to commensal bacteria disruption include colitis, malnutrition, nonalcoholic fatty liver disease, atherosclerosis, viral infection, colon cancer, autoimmune arthritis, and type 1 diabetes.[106,108,109]Much of the research in the area of commensal bacteria and host health are done in animal models or *in vitro*, as well as in epidemiological studies, but clinical trials are emerging,

particularly in the area of treatment of conditions with beneficial bacteria.[107,108] For example, fecal transplantation is regarded as an effective treatment for CDI, and research of this approach in ulcerative colitis is evolving.[110,111]

The topic of the microbiome and host health is an emerging area of research. With the possible exception of consuming a healthy diet that includes nutrient-dense food and complex carbohydrates, the implications of this research on interventions to influence human health are unknown.[107,108] Possibly more recommendations related to this new and intriguing topic will be forthcoming.

Human Immunodeficiency Virus/Acquired Immunodeficiency Syndrome

Lymphocytes, which regulate the immune response, are destroyed with the active human immunodeficiency virus (HIV); specifically, the CD4+/CCR5+ T lymphocytes, which are mostly contained in gut-associated lymphoid tissue, are lost.[112] Altered nutritional status may influence disease progression and survival in patients with acquired immunodeficiency syndrome (AIDS). Wasting syndrome, as defined by a loss of 10 percent of baseline body weight, plus either chronic diarrhea or weakness and fever, is considered an AIDS-defining illness. A direct relationship between weight loss and an increased risk of opportunistic infections and death has been observed in patients with AIDS.[34,113] The loss of lean body mass starts early in HIV-positive patients. An average weight loss of 16 percent has been reported, from pre-illness weight until death from AIDS. The cause of weight loss is multifactorial but may be correlated with food insecurity and lack of antiretroviral therapy.[112,114] Malabsorption and a hypermetabolic rate are also factors for weight loss to varying degrees. A hypermetabolic response is not observed in all HIV-positive patients.[112,115,116] However, several studies have observed mildly increased resting energy expenditure in HIV-infected subjects, but not TEE.

Individuals with HIV may have multiple macronutrient and micronutrient deficiencies.[117] Diet history, weight history, and physical examination may be effective tools for evaluating nutritional deficiencies and nutrition risk.[5,34] Caution is needed when interpreting many of the biochemical studies. Visceral proteins may be altered due to inflammation, making them difficult to interpret for nutrition status. Serum levels of micronutrients are not necessarily representative of a nutrient status and may be altered by disease state.[33,34] It remains unclear if low nutrient status is an independent marker of more advanced disease or if nutrient deficiency plays an important role in the progression of AIDS.[118] To date, clinical trials have found the risk of disease progression to be increased, decreased, or unchanged in association with various vitamin and/or mineral supplements.[34] Therefore, with perhaps the exception of vitamin A in children, micronutrient supplementation is rarely recommended for this population, unless there is a documented deficiency. More research is needed before specific recommendations can be made regarding vitamin/mineral supplementation in AIDS. For patients using nutritional supplements, a careful review of supplement use and potential drug-nutrient interactions should be part of the nutrition assessment of patients on antiretroviral therapy.

Effects of Nutrition during Stages of Life

INFANTS

Colostrum and breast milk provide numerous immunologically active components and hormones, such as immunoglobulins (especially immunoglobulin A), lactoferrin, bifidus factor, lymphocytes, and macrophages.[119] They aid in gut maintenance, inhibit bacterial overgrowth of pathogenic flora, and provide both specific and nonspecific defense against infection. Bifidus factor helps to promote the growth of *Lactobacillus bifidus*. Subsequent metabolites help to acidify an infant's stools and retard the growth of enteric pathogens such as yeast, *E. coli*, and *Shigella*.[120] The American Academy of Pediatrics has concluded that in developed countries breastfeeding reduces the incidence and/or severity of diarrhea, lower respiratory infection, otitis media, bacteremia, bacterial meningitis, botulism, urinary tract infections, and necrotizing enterocolitis.[121] Breastfeeding can also reduce the risk of infection in comparison with infant formulas prepared with contaminated water.[122]

The American Academy of Pediatrics recommends breastfeeding infants exclusively for 6 months and to continue for at least 12 months (supplementing with iron-enriched solid foods after 6 months).[121] However, when the mother has untreated active tuberculosis or HIV infection, breastfeeding is not recommended.[121,122] In these instances, commercial infant formula is recommended, though this may not be feasible in developing countries without alternatives for breastfeeding.

ELDERLY PATIENTS

As a person ages, he or she is at an increased risk for suboptimal nutrient intake.[123,124] This is due to factors that limit the desire to eat or the ability to purchase or prepare nutritious meals. Specific nutrient deficiencies may occur as the result of comorbidities and/or polypharmacy. Decreased T-cell functioning in elderly persons has been associated with a suboptimal nutritional status.[125]

Undernutrition in elderly persons is more common among the oldest persons, the institutionalized, some ethnic minorities, and those of lower socioeconomic status.[126] The RDAs for elderly persons are established for those between the ages of 50 and 70 years and over 70 years of age.[58]

A decline in many immune responses is observed in most, but not all, elderly persons.[127] Adequate nutrition and supplementation may enhance some aspects of the declining immune response observed in elderly persons, yet it is still unclear what should be supplemented or how much. In healthy elderly persons, an increase in delayed hypersensitivity has been observed with daily supplementation of either a multivitamin/mineral tablet or 200 mg of vitamin E (a 200-mg dose had a more significant effect than either 60 or 800 mg).[85,128] Vitamin E supplementation in elderly persons living in nursing homes may reduce the risk of respiratory infections and influenza.[85] A decreased incidence of infection-related illness was also observed in a group of elderly subjects who used a complete multivitamin-mineral supplement.[129] Good dietary sources of eicosapentaenoic acid and docosahexaenoic acid, as well as selenium, have been shown to have the ability improve or maintain positive dietary status in elderly persons.[130] Vitamin D supplementation is indicated for reduced risk of falls and fractures.[131] Further research is needed to confirm the type and amount of micronutrient supplementation that may facilitate optimal immune function in the elderly population. Until then, many researchers contend that a moderate-dose, complete multivitamin/mineral supplement may be of benefit.

Risk of Infection from Nutrition Support

ENTERAL NUTRITION

The use of enteral nutrition (EN) allows for the provision of nutrients within the gastrointestinal tract when the patient is unable to consume food on his or her own. Candidates for EN support include those who are unable to swallow food safely (e.g., following cerebral vascular attack or head injury), critically ill persons, ventilated patients, and head/neck cancer patients.[132,133] EN feeding tubes may be placed either nasally or surgically (i.e., gastrostomy, jejunostomy) with the final tip of the feeding tube delivering nutrients either gastrically or enterically.

Compared to parenteral nutrition (PN; described in the next section), EN is associated with a reduced risk of infection and, in some populations, reduced length of hospital stay. EN utilizes the gastrointestinal tract and stimulates normal digestive physiology and process.[134] Unlike PN, nutrients are metabolized via the liver prior to entering systemic circulation.[132] Since nutrients are delivered enterally, EN maintains gut integrity that further maintains gut-associated lymphoid tissue function.[134] This primary host defense may further reduce the risk for bacterial translocation and infection. In critically ill patients, EN delivered within 48 hours of admission into the ICU has shown to improve outcomes.[135] This "early" feeding is associated with reduced complications and ICU length of stay. For the critically ill, obese patient, recommendations tend to favor the use of hypocaloric feeding (i.e., reduced-calorie, high-protein delivery) of nutrition support.[135] Studies indicate that this patient population has reduced ICU length of stay, reduced insulin requirements, and improved wound healing.[135,136,137] It should be noted that many studies on this feeding modality are short term; the optimal length of delivery needs to be determined.

A relatively new formula category known as "immune enhancing" or "immune modulating" formula has been available since the 1990s and has been promoted for their benefits for the immune system.[138] This category of formula is promoted to enhance the immune response while attenuating the inflammatory process. It contains at least one (generally more) of the following nutrients: arginine, glutamine, nucleotides, omega-3 fatty acids (usually as fish oil). Immune modulating formulas have been studied fairly extensively, but many clinical trials have not been robust, and comparing one study to another may be difficult due to formula variability. However, based on meta-analysis and systematic reviews, the conglomerate data do indicate that there may be some benefit, such as reduced infectious complications, reduced mortality, and reduced length of stay in the ICU and hospital for patients receiving immune modulating formula.[139,140,141,142] Benefit appears to be limited to specific patient populations, including those with head and neck cancer; trauma; burn; those who are critically ill; ventilated patients; and patients with mild sepsis.[135,142] It is important to note that not all studies support these benefits in these populations.[142] There is a possibility that benefit may be derived from using a specific formula composition (e.g., elevated in fish oil) in the appropriate patient population (e.g., trauma versus medical ICU).[140,142] Lastly, caution is still advised regarding the use of formulas supplemented with arginine in severely septic patients.[137,142]

Enteral formulas can easily become contaminated during preparation, addition of formula/additives to the feeding bag, or manipulation of the tubing. Heavy initial contamination or inappropriately long hang times of the formula or delivery set can result in dangerous concentrations of microorganisms.[143] In

some cases, severe septicemia apparently resulted from EN contamination. Bacterial contamination of EN may be minimized by mixing/diluting formula in a centralized location and ensuring that caregivers follow strict handwashing.[144] Monitoring of recommended hang time for enteral formula is also important.

Open feeding systems should be removed after 8 hours, whereas sterile closed systems may remain hanging for up to 24 to 48 hours. Administration sets should be replaced every 24 hours or per manufacturer's recommendation for closed systems.[144,145] Sterile technique is recommended for high-risk groups, such as bone marrow transplant recipients, patients with AIDS, or neonates. This may include sterile water for reconstituting formula or water flushes. Healthcare personnel are urged to use undiluted/canned formula or prefilled containers if possible and minimize additives.

Many hospitalized patients receiving EN are at risk of CDI from use of certain antimicrobial agents. Acquisition of *C. diff* has been reported to be more common in patients receiving EN compared with those consuming an oral diet.[98] Possible reasons include an increased risk of contamination of formula or delivery set and lack of fiber in the enteral formulas studied. The risk was highest with post-pyloric tube position, possibly resulting from delivery of the formula below the gastric acid barrier.

PARENTERAL NUTRITION

Some patients will be unable to ingest adequate nutrients by either the oral or enteral routes. Based on the American Society for Parenteral and Enteral Nutrition, these patients should be considered PN candidates, especially if inadequate intake persists or is expect to persist for 7 to 14 days.[135] PN is recommended sooner in those who are critically ill and/or already malnourished. This population may include patients with Crohn's disease as well as those who are critically ill and do not tolerate EN support, and those with short bowel syndrome, a prolonged postoperative ileus, or intestinal obstruction.[132]

Compared to EN, PN has been identified as a greater risk factor for catheter-related bloodstream infections.[134,146] This risk may be greater with compounded PN solutions compared to ready-to use solution.[146] Following strict compounding techniques and appropriate catheter insertion and management practices reduce the risk of PN-associated infection.[147] Lack of use of the intestinal tract, as is often the case with PN, results in loss of functional integrity of the intestine and reduced gut-associated lymphoid tissue response.[134]

Lipid emulsions are the most likely component of PN to foster bacterial or fungal proliferation because of their alkaline, iso-osmotic environment.[147] Total nutrient admixtures support microbial growth better than amino acid/dextrose solutions, though amino acid/dextrose solutions can support fungal growth.[92] The CDC recommends a maximum infusion time of 12 hours for parenteral lipids.[148] Amino acid/dextrose (with or without lipids) solutions should not infuse longer than 24 hours.

A 0.22-μm bacterial retentive filter has been recommended during administration of PN using amino acid/dextrose solutions.[147] PN solutions containing lipid emulsions require a 1.2-μm filter. Although a 1.2-μm filter will not reliably filter common bacterial organisms such as *Staphylococcus epidermidis* or *E. coli,* it will filter larger organisms such as *Candida albicans*, along with particulate matter and air. Guidelines to minimize contamination during compounding, storage, or administration of PN are reviewed elsewhere.

ASPIRATION PNEUMONIA

Numerous studies have tried to determine the optimal nutrition regimen to minimize the risk of aspiration pneumonia. Risk of aspiration is not minimized by use of PN compared with EN. Occurrence of pneumonia has not been shown to decrease with the use of PN compared with EN. In fact, some studies have shown an increased incidence of pneumonia with PN, possibly because of its effect on immune function.[149] Continuous infusion of EN is usually recommended compared with intermittent or bolus methods to reduce aspiration. Some research favors an intermittent schedule for EN into the stomach, because it may allow a temporary decrease in gastric pH between feedings. Gastric pH can play a role, because a more basic environment may foster bacterial overgrowth.[150] However, intermittent feeding has not been shown to decrease the incidence of aspiration compared with continuous infusion.[149,150,151,152] Continuous infusion is believed to reduce the risk of excessive gastric residuals, distention, and subsequent aspiration.[150] Therefore, continuous infusion with prokinetic agents, if needed, is more routinely recommended than bolus or intermittent feedings.

The presence of a nasogastric tube prevents complete closure of the lower esophageal sphincter, which may facilitate migration of gastric bacteria into the lungs. However, the use of percutaneous gastrostomy tubes has not proven to decrease the risk of aspiration.[153,154] Intuitively, small bowel feeding should reduce the risk of aspiration compared with gastric feeds because many patients have a potential for delayed gastric emptying as a result of disease state or medications. Several studies have shown lower rates of aspiration in patients fed with postpyloric or jejunostomy tubes compared with gastric feeds.[134] However, others have failed to show a significant difference in aspiration.

An individual's risk of aspiration depends on many factors (e.g., diminished mental status, absence of a gag reflex, use of mechanical ventilation, recumbent body position, reduced lower esophageal sphincter pressure, delayed gastric emptying). It would seem prudent that patients with the highest risk of aspiration would be the most likely to benefit from continuous feedings via jejunal tube, with the head of the bed elevated to 30 to 45 degrees.[134]

Conclusions

The current face of malnutrition is a dichotomy of overnutrition and undernutrition. Both are considered a form of malnutrition and both may have negative implications on the immune function and health outcomes. Nutrition can play a critical role in reducing infectious morbidity and mortality and should be promoted and encouraged in the hospital and clinical setting. Populations at risk for even marginal nutritional alterations should be evaluated and assessed for their nutrient status. The optimal nutrition regimen must be individualized on the basis of the disease state or type of infection, degree of malnutrition, and route of nutrition support. It is now clear that EN, especially when initiated early, supports the immune system better than PN. Overfeeding may alter immune defenses and should be avoided, especially during critical illness. Micronutrient deficiencies should be corrected, but with the understanding that most persons have an upper and lower threshold for optimal immune function.

Future Trends

Current research has consistently supported the need and benefits of early feeding after injury or illness. Research efforts will continue to identify the benefits of earlier feeding and the most beneficial nutritional formulas. In addition, the roles of alternative nutritional therapies have continued to capture the interest of the general public. The future of gut microbiota on the immune function may possibly provide some answers on the prevention of chronic and acute illness and may serve as a form of therapy for specific conditions.

International Perspective

Worldwide, the greatest impact on public health may come from correcting overnutrition or obesity and undernutrition, from protein, energy, vitamin A, zinc or iron deficiency, and other micronutrients both in developing and developed countries. The global epidemic of obesity may change the perspective of health interventions, but the problem of undernutrition still exists and should be addressed.

Supplemental Resources

Academy of Nutrition and Dietetics. Available at: **http://www.eatright.org**.

American Dietetic Association's Evidence Analysis Library. Available at: **http://andevidencelibrary.com/**.

American Society for Parenteral and Enteral Nutrition. Available at:**" http://www.nutritioncare.org**.

Cochrane Reviews. The Cochrane Collaboration website. Available at: **http://www.cochrane.org/cochrane-reviews**.

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Name *(Required)* Varghese John

Email *(Required)* trustvjk@gmail.com

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

Section 7

Infection Prevention for Practice Settings and Service-Specific Patient Care Areas

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Ambulatory Care

Author(s): Joann Archer, BTech MA
Educator/Consultant

Provincial Infection Control Network
Prince George, British Columbia, Canada

Bruce Gamage, RN, BSN, CIC
IC Consultant

BC Centre for Disease Control
Vancouver, British Columbia, Canada

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Abstract

Healthcare is shifting from inpatient acute care to a variety of outpatient ambulatory and community care settings ranging from physician offices to ambulatory surgery centers. As this shift occurs, the risk of acquiring a healthcare-associated infection in the ambulatory care settings is increasing. Risk factors associated with this increase are the type and number of invasive procedures performed, as well as the client's advancing age and number of comorbidities. Standard precautions remain the basic approach to the prevention of healthcare-associated infections in ambulatory care settings. Careful adherence to infection prevention principles adapted for the outpatient arena will minimize infection risks to patients, healthcare personnel, and family members/visitors. This chapter addresses infection prevention and control in ambulatory care settings except ambulatory surgery, dialysis, and oncology centers, which are all addressed in other chapters.

Key Concepts

- Standard Precautions are the key approach to preventing healthcare-associated infections and improving patient safety in all ambulatory care settings.

- The risk of healthcare-associated infections in an ambulatory setting increases as the type of procedures become more complex and the number of invasive procedures conducted increases.
- Administration is accountable to provide proper resources and equipment to maintain safe and effective infection prevention practices.
- At least one healthcare personnel should be educated and trained in infection prevention practices and accountable to maintain safe, effective policies and procedures in the ambulatory care setting.
- Assessment for the introduction of new equipment and procedures should be continuous and ongoing to ensure that there are no gaps in effective cleaning and disinfection of equipment/instruments.

Background

Influenced by increasing healthcare costs and the increasing number of healthcare consumers, healthcare delivery has steadily been shifting away from the acute care setting to ambulatory care services. Where the majority of healthcare in the past was provided as an inpatient, much of the same care is now delivered in a variety of community-based outpatient settings. Ambulatory care services now include diagnostic testing, invasive procedures, and therapeutic care.

For this chapter, ambulatory care is defined as any care provided in a setting where individuals do not remain overnight (e.g., physician offices, urgent care centers, oncology clinics, hemodialysis clinics, hospital or nonhospital-based outpatient clinics, and ambulatory surgery clinics). Healthcare personnel (HCP) is defined as any person (paid or volunteer) providing services who has the potential to be exposed to infections or infectious materials such as blood or bodily fluids, contaminated equipment, contaminated environmental surfaces, and contaminated air.

Because transmission of infections is a risk in any healthcare setting, developing and implementing an infection prevention and control program is always integral to patient safety. It is important that individuals with administrative oversight in ambulatory care settings ensure that sufficient resources are in place to both implement and sustain effective infection prevention and control programs. A well-developed infection prevention and control program includes the designation of an infection preventionist (IP), formal policies and procedures, comprehensive education of all HCP, a physical environment that is conducive to preventing infections, and sufficient equipment and supplies to consistently apply infection prevention principles such as Standard and Transmission-based Precautions (e.g., gloves, gowns, single-use equipment). The IP needs to conduct an annual infection prevention assessment to establish priorities regarding high risk, high volume, and problem prone activities. Because new invasive procedures may be implemented at any time during the year, a process needs to be developed to identify them in their proposal phase prior to implementation to ensure proper cleaning and disinfection procedures. Ambulatory care facilities also need to adhere to local, state, and federal requirements for reportable disease and outbreak reporting, including all health department regulations and state/local statutes.

Risk Factors in Ambulatory and Primary Care Settings

Historically, the risk of healthcare-associated infections (HAIs) in ambulatory and primary care settings have been low, primarily because the patients were more likely to be healthier than those treated in inpatient settings and because less invasive procedures were conducted. In addition, ambulatory visits, by their nature, are relatively short and predominantly noninvasive. However, patients being treated in ambulatory settings now have higher acuity because of the shift in care delivery from hospitals to

alternative settings. In addition, invasive procedures and advanced technologies are being used with increasing frequency in outpatient settings. All of these factors increase the potential risk for HAI in these patients.[1,2] Yet, the potential for oversight for infection prevention and control programs may be more limited in these settings than in more traditional acute care settings. Often an IP will be assigned multiple ambulatory clinics located in different areas rather than assigned to one healthcare facility.

Another risk factor for transmission of infections in ambulatory care settings is the clustering of patients and significant others in common waiting areas prior to healthcare screening. In addition, they frequently have unmonitored movement throughout the facility, thereby increasing the potential for communicable disease transmission, particularly exposure to droplet or airborne diseases. Their movement, for instance, may be between waiting rooms, bathroom facilities, exam rooms, laboratory, pharmacy, and other diagnostic areas. Patients presenting with undiagnosed communicable diseases such as bloodborne pathogens, multidrug-resistant pathogens, and even tuberculosis (TB) may put other patients and HCP at risk.[1]

Basic Principles

Adhering to Standard Precautions is the minimum practice that applies to preventing transmission of infections in healthcare services, regardless of the setting or the suspected or confirmed infectious status of the patient. Standard practices include: (1) hand hygiene, (2) appropriate use of personal protective equipment (PPE), (3) safe injection practices, (4) safe handling of potentially contaminated surfaces in the environment and of noncritical equipment, and (5) respiratory hygiene/cough etiquette.[3,4]

HAND HYGIENE

Hand hygiene practices in ambulatory care settings are the same as in any other healthcare setting. Recognizing the importance of hand hygiene in outpatient care settings, the World Health Organization (WHO) launched a new guide on hand hygiene in ambulatory settings where patients are not admitted as inpatients to a hospital.[4] In fact, WHO provides posters using the five moments for hand hygiene approach specific to outpatient settings such as dialysis, laboratories, general practice, and emergency clinics. Ambulatory care settings that are accredited by The Joint Commission monitor adherence to hand hygiene practices as an indicator of safe infection prevention practices. As a universal indicator of safe, effective infection prevention practices, all ambulatory care settings are encouraged to monitor hand hygiene adherence reporting compliance to the facility administration. Hand hygiene practice is discussed in detail in **27. Hand Hygiene**.

USE OF PERSONAL PROTECTIVE EQUIPMENT

Appropriate use of PPE, including gloves, gowns, and barrier masks with or without face shields, is essential to safe infection prevention practices in ambulatory care settings. PPE should be easily accessible to HCP throughout the facility. Appropriate use of PPE is discussed in detail in **28. Standard Precautions**.

SAFE INJECTION PRACTICES

Although the prevention of transmission of bloodborne pathogens has always been an essential focus of Standard Precautions, unsafe injection practices have more recently been associated with transmission of Hepatitis B virus (HBV), Hepatitis C virus (HCV), and human immunodeficiency virus (HIV) implicating

an area of improvement in Standard Precaution practices.[5] The following safe injection practices have been recommended for any HCP delivering injectable medications to a patient.[6]

1. Use aseptic technique when preparing and administering injectable medications.
2. Cleanse the access diaphragms of medication vials with 70 percent alcohol before inserting a device into the vial.
3. Never administer medications from the same syringe to multiple patients, even if the needle is changed or the injection is administered through an intervening length of intravenous tubing.
4. Never reuse a syringe to enter a medication vial or solution.
5. Do not administer medications from single-dose or single-use vials, ampoules, or bags or bottles of intravenous solution to more than one patient.
6. Do not use fluid infusion or administration sets (e.g., intravenous tubing) for more than one patient.
7. Dedicate multidose vials to a single patient whenever possible. If multidose vials will be used for more than one patient, they should be restricted to a centralized medication area and should not enter the immediate patient treatment area (e.g., operating room, patient room/cubicle).
8. Dispose of used syringes and needles at the point of use in a sharps container that is closable, puncture-resistant, and leak-proof.
9. Adhere to federal and state requirements for protection of HCP from exposure to bloodborne pathogens. Needleless or safety engineered devices should be employed whenever possible.

SAFE HANDLING OF POTENTIALLY CONTAMINATED ENVIRONMENTAL SURFACES AND CONTAMINATED NONCRITICAL EQUIPMENT

The safe handling of contaminated environmental surfaces and noncritical equipment in an ambulatory clinic is no different than these procedures in any other heathcare settings. General guidelines for cleaning and disinfection of environmental surfaces are:

1. Establish policies and procedures for routine cleaning and disinfection of environmental surfaces. Prioritize those surfaces in close proximity to patients and those that are frequently touched.
2. Select Environmental Protection Agency (EPA)-registered disinfectants or detergents/disinfectants with label claims for use in healthcare.[7] Follow manufacturers' recommendations for use of cleaners and EPA-registered disinfectants (e.g., amount, dilution, contact time, safe use, and disposal).
3. Clean the frequently touched surfaces of offices, office equipment and examination rooms with an EPA-registered low-level disinfectant daily or when visibly soiled. Phenolics, iodophors, quaternary ammonium compounds, and hydrogen peroxide-based products are appropriate for use in disinfection of surfaces. Do not use phenolics in clinical areas where care is provided to infants.[7]
4. The examination tables should be covered with a disposable paper or linen that is changed between patients. More thorough cleaning and disinfection should be done if contamination is visible.
5. Ensure that any toys or other materials used for diversion found in the waiting room are able to withstand regular cleaning with hot water and detergent. Toys with nonabsorbable surfaces are highly recommended. Avoid plush toys, as they are difficult to clean and disinfect.
6. Clean floors in the waiting area and examination rooms at least daily.
7. Clean and disinfect the HCP and patient restrooms at least daily and whenever visibly soiled. The frequency of cleaning will be determined by the volume and frequency of use.

8. A diaper changing area should be supplied with disposable paper, disinfectant wipes, and instructions for wiping after each use. It should also be routinely cleaned and disinfected at least once daily and whenever visibly soiled.
9. Develop written policies and procedures for the cleanup of spills of blood, vomitus, or feces. Clean spills involving blood or body fluids contaminated with blood onto floors and other surfaces first with detergent, and then again using an EPA disinfectant solution. Products must be diluted and stored according to manufacturer's instructions.[7](See **101. Occupational Exposure to Bloodborne Pathogens**, and 105 Minimizing Exposure to Blood and Body Fluids.)

General guidelines for the cleaning and disinfection of noncritical equipment are:

1. Use disposable equipment dedicated for single patient use when possible.
2. Clean and disinfect reusable noncritical equipment that has been in direct contact with the patient (e.g., stethoscopes, blood pressure cuffs) before use in the care of another patient with an EPA-approved cleaner-disinfectant.[8]Clean the handle and body of instruments such as otoscopes and ophthalmoscopes in a similar fashion.
3. The role of stethoscopes and other examining devices in transmitting microorganisms is unclear. However, stethoscopes have been shown to be contaminated with bacteria (e.g., methicillin-resistant *Staphylococcus aureus*[MRSA], vancomycin-resistant enterococci [VRE]).[9]Thus, the stethoscope tubing and diaphragm should be cleaned and disinfected after use between patients. EPA-approved disposable equipment wipes containing quaternary ammonias are preferred.
4. Equipment that is visibly soiled should always be cleaned and disinfected before reuse.
5. Contaminated equipment should be handled in a manner that prevents exposure of the HCP's skin, mucous membranes, clothing, and surrounding environment. Procedures should be established for assigning responsibility for routine cleaning of all patient care equipment.

6. Contaminated sharp items should be disposed of immediately in "point-of-use" receptacles. These receptacles need to be puncture proof, impermeable, have a tight-fitting lid, clearly labeled with biohazardous signage, and readily available in all clinical areas. The person using a disposable sharp item is responsible for its safe disposal into an appropriate container. Examples of clinical contaminated sharps include needles, stitch cutters, scalpel blades, and any other sharp object that may have been in contact with blood, body fluids, or exudates. Needles must not be recapped, purposely bent, broken, removed from disposable syringes, or manipulated by hand. Do not uncap a needle unless an appropriate container is accessible for immediate disposal after its use.

   Regardless of the purpose for which a clinical sharp is used, if it is labeled single use, it must be disposed of after single use.

7. Mouthpieces and resuscitation bags should be available for staff performing cardiopulmonary resuscitation (CPR). This equipment requires cleaning and disinfection if reusable before use on another patient.[1]If single-use equipment is employed, dispose of it immediately after use.

8. Ballpoint pens, patient charts, computer keyboards, and computer mice can be contaminated with microorganisms that can be transmitted by hands to other environmental surfaces. Because these items are rarely cleaned, hand hygiene before and after patient contact is necessary to minimize the potential transfer of infectious agents from equipment to patients. Computer components such as keyboards and mice should be cleaned regularly using a mild, noncorrosive cleaner. Plastic covers are also available that make cleaning easier.[8,10,11,12]

9. Blood pressure cuffs are usually placed on intact skin, so the risk of transmission of infectious agents is minimal. Cuffs should not be placed in direct contact with damaged or nonintact skin. In some settings, such as in ambulatory operation centers, the use of one-time patient use blood pressure cuffs is becoming more common.
10. Disposable plastic sleeves should be used with reusable electronic thermometers. Clean the thermometer body and disinfect regularly (at least daily) and whenever soiled. Use of temporal artery thermometers is becoming more common since they do not touch mucous membranes, minimizing the risk of pathogen exposure.
11. Glucose monitoring devices have been identified as sources in Hepatitis B and C outbreaks. Thus, it is recommended that glucometers and fingerstick devices should never be shared. If glucometers must be shared between patients, they must be clean and disinfected between each patient use according to manufacturer's guidelines.[13]

Table 48-1 gives examples of environmental items that are often contaminated.

Table 48-1 Examples of Environmental Items That Have Been Shown to Harbor Microorganisms*

Bed linen[14]	Door handle[12,18,19]	Stethoscope[25,26]
Bed rail[15,16]	Electronic thermometerezembed [20]	Suctioning and resuscitation equipment [27]
Bedside table[15]	[20]	Table, staff work table/charting area[26]
Blood pressure cuff[8]	Hydrotherapy equipment[21]	Telephone, mobile phones[15,28,29]
Call bell[15]	Infusion equipment[12]	Television[18]
Chair[16]	Light switch[18]	Toilet/commode[15,18]
Clean gloves that have touched room surfaces only [17]	Overbed table[12]	Tourniquet[30]
Computer keyboard[8,16]	Phlebotomy tourniquet[22]	
	Pillow/mattress[23]	
	Privacy curtains[24]	

*Microorganisms such as methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, *Clostridium difficile*, *Acinetobacter baumannii*, respiratory syncytial virus, influenza virus, and others.

RESPIRATORY HYGIENE/COUGH ETIQUETTE

Respiratory hygiene and cough etiquette, components of Standard Precautions, are key measures to prevent transmission of respiratory infection including influenza in the ambulatory setting. Implement respiratory hygiene stations including barrier masks, disposable tissues, waterless hand sanitizers, and cough etiquette instructions at entrances to the ambulatory care facility and place strategically throughout the facility based on size and need. The following are specific steps to take for implementation:

- Post signs at entrances with instructions to patients with symptoms of respiratory infection to:

- Cover their mouths/noses when coughing or sneezing
- Use and dispose of tissues
- Perform hand hygiene after hands have been in contact with respiratory secretions

- Provide tissues and no-touch receptacles for disposal.
- Provide resources for performing hand hygiene (e.g., alcohol-based hand rub [ABHR]) in or near waiting areas.
- Offer masks to coughing patients and other symptomatic persons upon entry to the facility.
- Provide space and encourage persons with symptoms of respiratory infections to sit as far away from others as possible. If available, facilities may wish to place these patients in a separate area while waiting for care.

ADDITIONAL RECOMMENDATIONS FOR PREVENTION OF INFECTIONS

Specific syndromes involving diagnostic uncertainty (e.g., diarrhea, productive cough, febrile respiratory illness, or febrile rash) are routinely encountered in ambulatory settings. Facilities should develop and implement systems for early detection and management of potentially infectious patients at initial points of entry to the facility. To the extent possible, this includes prompt placement of such patients into a single-patient examination room. The following special arrangements should be considered for patients who may be contagious:

- Screen patients at the time the office visit is scheduled.
- Make an effort to see these patients at the end of the day or when the waiting area is least busy.
- Place a barrier mask on patients who exhibit signs of respiratory illness. Ensure that the patient understands respiratory hygiene.
- Quickly triage patients out of common waiting areas and into a private examination room.
- Close the door of the examining room and limit access to the patient by visitors and staff members who are not immune to the suspected disease.
- Triage patients who exhibit signs and symptoms of respiratory illness into a negative pressure room, if available.

Table 48-2 provides a sample of triage questions that can be used to screen patients for potentially contagious illness.

Table 48-2 Sample Triage Questions

Name:_______________ Date:_______________ Time:_______________	
Are you experiencing any of the following symptoms?	No Yes
2. Has it caused you to vomit? (screen for pertussis)	No Yes
4. Feeling feverish or have had a fever in the last 24 hours	No Yes
6. New onset of diarrhea	No Yes
If you answer yes to any of the above questions, please notify the receptionist. You may be placed in a private examination room and healthcare providers may wear a mask.	

Management of Multidrug-resistant Organisms

Standard Precautions are recommended in most ambulatory care settings to prevent transmission of multidrug-resistant organisms (MDROs). The Centers for Disease Control and Prevention (CDC) guidelines for MDROs states that: "In ambulatory settings, use Standard Precautions for patients known to be infected or colonized with target MDROs, making sure that gloves and gowns are used for contact with uncontrolled secretions, pressure ulcers, draining wounds, stool incontinence, and ostomy tubes and bags."[31] The risk of spread in outpatient facilities is reduced because of short stays, lower intensity of care, and relatively healthy patients.[31] Yet, with MRSA, VRE, *Clostridium difficile,* extended spectrum beta-lactamase-producing organisms, and carbapenem-resistant Enterobacteriaceae on the rise throughout healthcare facilities and the community, there are often questions and some confusion from HCP and patients in outpatient settings related to the difference in recommendations to use Contact Precautions for inpatients and not for outpatients. Studies have shown that clinic patients carry MDR0[31,32] and outpatient environments can become contaminated.[33,34] These studies did not report transmission to patients, although there was possible transmission to HCP.

Although there is presumably less risk of environmental contamination in these settings, surface disinfection for frequently touched (and frequently overlooked) surfaces should still occur on a regular basis; these surfaces include door handles, cabinet and drawer pulls, toilet handles, sink faucet handles, light switches, and computer keyboards. However, if transmission in an outpatient setting is detected, more stringent practices may need to be implemented. It may be prudent to develop specific procedures for prevention of MDRO transmission for areas in which high-risk patients are seen, such as infusion centers (hemodialysis, chemotherapy units).

For diagnostic and treatment centers located in hospitals that treat both inpatients and outpatients, it may be wise to develop a set of practices that applies to both categories of patients. For example, a gastrointestinal endoscopy unit performing procedures on inpatients and outpatients may institute contact precautions for all patients with MDROs and *C. difficile*. Patients in these settings are likely to be in the area for a longer time than in a clinic and, because of the procedure itself, may contaminate the environment. In these settings the use of contact precautions for patients known to be positive for an MDRO may be indicated.[35,36,37]

All healthcare services should develop an antibiotic stewardship campaign, including education of patients about how and when to use antibiotics to ensure they are effective.

TRANSMISSION-BASED PRECAUTIONS

In addition to Standard Precautions, Transmission-based Precautions are used for patients known or suspected to be infected or colonized with certain microorganisms.[3] A sample list of organisms and the precautions to be applied is provided in Table 48-3.

Table 48-3 Microorganism Transmission Routes and Precautionary Measures[3,35]

Transmission Route	Diseases (examples)	Precautions Required

Airborne	Pulmonary tuberculosis Disseminated zoster Rubeola (measles) Varicella (chickenpox)	N95 particulate respirator Eye protection Move to private examination room Close door Negative pressure room preferred
Droplets	Influenza Mumps Pertussis Rubella Viral respiratory infections (e.g., adenovirus, parainfluenza, rhinovirus, respiratory syncytial virus) Parvovirus B-19 Invasive group A streptococcus	Surgical mask Eye protection Hand hygiene
Direct contact	Infectious diarrhea (e.g., *Campylobacter, Norovirus, Rotavirus, Salmonella, Clostridium difficile*) Major burn wound infection Desquamating skin disorders Scabies Varicella Zoster Viral respiratory infections (in addition to droplet/airborne)	Gloves Fluid-resistant gown Hand hygiene

CONTACT PRECAUTIONS

Contact Precautions are used for patients known or suspected to be colonized and/or infected with microorganisms that can be spread by direct contact from the patient or by indirect contact with environmental surfaces or patient care equipment (e.g., zoster, scabies). Any healthcare provider likely to have direct contact with a patient suspected or known to have an infectious disease that is spread by direct or indirect contact should wear gloves and a fluid-resistant gown during contact with the patient.

DROPLET PRECAUTIONS

Droplet Precautions are used for patients known or suspected to have microorganisms transmitted by droplets >5 microns (e.g., mumps, influenza). These droplets may be produced during coughing, sneezing, and talking or during certain procedures such as suctioning or bronchoscopy. These particles are propelled a short distance, <6 feet, and do not remain suspended in the air. Any healthcare provider coming within 6 feet of a patient suspected or known to have a droplet-transmitted infectious disease should wear a fluid-resistant surgical or procedural mask and eye protection. The patient should be

asked to wear a barrier mask if tolerated and taught to use respiratory etiquette when coughing and/or sneezing.

AIRBORNE PRECAUTIONS

Airborne Precautions are used for patients known or suspected to have microorganisms transmitted by the airborne route. These may consist of small particle residue (≤5μ) that results from the evaporation of large droplets or dust particles containing skin squames and other debris (e.g., TB, measles). These particles can remain suspended in the air for long periods of time and are spread by air currents within a room or over a long distance.

Although Airborne Precautions are rarely needed in the ambulatory care setting, procedures should be in place to manage clients who may have infections such as pulmonary TB, measles, or chickenpox. In the event of emergence of a new pathogen, such as novel strains of influenza, severe acute respiratory syndrome, or Middle East respiratory syndrome coronavirus, the need for Airborne Precautions may be indicated until the routes of transmission of the new microorganism are determined.

Office personnel should be screened for immunity to varicella and measles, either through natural exposure in childhood or vaccination. It is recommended that only immune HCP enter a room of a person suspected to have measles, varicella, or other communicable illnesses. In that case, the HCP's immunity is sufficient and a respirator is not required. Otherwise, any healthcare provider entering the room occupied by a patient suspected or known to have an airborne-transmitted infectious disease should, at a minimum, don an N95 respirator. The patient should be placed in a negative pressure room, if available. If a patient with a known airborne organism has been housed in a room, the door should remain closed and the room should not be used until there have been sufficient air exchanges to clear the room of any remaining airborne particles. This is typically for 1 hour, but may vary depending on ventilation available.[5]

See **29. Isolation Precautions (Transmission-based Precautions)**.

ASEPTIC TECHNIQUE

Where sites perform invasive procedures, maintain high standards of aseptic technique,[38]including:

- No pre-set up of sterile supplies, such as those used for surgery or vascular access
- Patient skin prep with recognized effective agents
- Physician hand scrub with recognized effective agents
- Training of assistive staff on sterile field setup (e.g., for minor plastic surgery under local anaesthetic) versus clean setup (e.g., for pelvic exams).

(See **30. Aseptic Technique**).

Education

Orientation and ongoing training are crucial in maintaining effective and up-to-date infection prevention practices in the outpatient setting. Topics include hand hygiene, respiratory hygiene, MDROs, cleaning, disinfection and sterilization, waste management procedures, and infection prevention practices (e.g., patient preparation before invasive procedures or line access, appropriate barrier use, and aseptic

technique). In addition, information related to occupational health issues, such as immunizations (HBV, influenza), exposures to bloodborne pathogens, and safe sharps handling should be included.

The needs of staff and resources available for education must be considered. Educational programs can be conducted in person at special educational programs or at staff meetings. Because of time and resource constraints, brief programs (10 to 20 minutes) are most effective and may need to be repeated to make sure all HCP are included. An alternative strategy is the creation and use of online educational modules. These modules can be developed to be site-specific and allow HCP flexibility in their schedules to access the education material. This option is especially useful for providing education to HCP in multiple sites, or for those HCP with irregular hours. Posters with brief messages can also be effective reminders on topics including hand hygiene, influenza vaccine, and respiratory hygiene. When ambulatory care sites are part of a healthcare system, it is important that new employees at remote sites are included in the central infection prevention orientation.

An area of special concern is education of HCP responsible for reprocessing medical devices and equipment. These HCP need education and training demonstrating competency initially and at regular intervals thereafter.[2]

Education of patients can be a vital bridge for infection prevention from the healthcare setting into the community. Active and passive means are available, depending on the demographic background of the population served.[2] Direct healthcare providers are encouraged to discuss hand hygiene, prudent antibiotic use, influenza and other immunizations, infection risk for overseas or other travel destinations, prevention of HIV/AIDS and other sexually transmitted diseases, hepatitis, and prevention of infection in specific at-risk populations (those with diabetes, cystic fibrosis, dialysis, chemotherapy patients). Passive means of education can include posters and pamphlets. Many are available from the CDC (**www.cdc.gov**). Educational programs can also be provided on televisions or computers in waiting rooms, using CDs, DVDs, Webcasts, or online modules.

Communication

The importance of good communication cannot be overemphasized. The IP responsible for ambulatory care facilities, whether they are standalone sites or hospital-based units, should network among IPs at local hospitals, other ambulatory care settings, professional organizations, and local and state health departments. There should be a formal communication network in place for communicating shared policies, disease alerts in the community, and pertinent information on patients or infectious diseases transferred from one site to another.

Reprocessing

Most ambulatory care settings perform some level of semicritical or critical instrument reprocessing. Refer to the CDC *Guideline for Disinfection and Sterilization in Healthcare Facilities*[7] and **32. Reprocessing Single-Use Devices**, and **31 Cleaning, Disinfection, and Sterilization**, for details. Challenges for IPs are the large variety of instruments, frequent introduction of new medical devices, and, sometimes, lack of adequate reprocessing instructions provided by the manufacturer. Education and competency for HCP responsible for instrument reprocessing is essential.

Monitor items that are reprocessed to ensure that the process is safe, cost effective, and follows manufacturer's instructions to avoid damage. All reusable instruments and medical devices need to have written procedures for cleaning and disinfection or sterilization. Written records should be maintained tracking the disinfection/sterilization process and results.

Where an IP is responsible to multiple sites, use the same policies and procedures for all of the sites to ensure consistency. During each site survey, determine if any new instruments have been acquired, and if so, ensure that the reprocessing is consistent with the manufacturer's recommendations, institutional policies, and CDC guidelines. For a more proactive approach, communicate the expectation to the outpatient site administration that the IP will be consulted for every new reusable medical device during the trial phase or before purchase. This provides more ability to determine the implications for reprocessing before equipment is already in use.

When adequate facilities for reprocessing are not available on-site, reprocessing can be outsourced to another facility or disposables can be employed. Outpatient sites affiliated with a hospital can clean and wrap instruments and send them to the central processing department for sterilization.

Monitor the room where instruments are reprocessed. The utility room must have negative air flow, adequate air changes per hour (check state standards), and enough space to set up a workflow from soiled to cleaned with a physical separation between the two. There should be policies in place to prevent disinfection of instruments in an examination or treatment room.

The IP must remain alert to the many invasive devices that are used in ambulatory care settings and be prepared to ensure reprocessing standards. Endoscopes are used in many specialties; for example, nasal endoscopes in otolaryngology and dentistry; hysteroscopes in gynecology and infertility clinics; arthroscopes in ambulatory surgery and rheumatology clinics; bronchoscopes in ambulatory surgery and endoscopy units; and cystoscopes in urology and ambulatory surgery. (See **55. Endoscopy**, and **64 Ambulatory Surgery Centers**.) Ultrasonography equipment for diagnostics and treatment may be used in cardiovascular clinics, urology, physical therapy, and gynecology. Procedures to ensure low/intermediate disinfection, high-level disinfection, or sterilization for contact with skin, mucous membrane, or sterile tissue, respectively, need to be developed.

Adherence to the CDC guidelines for disinfection and sterilization is essential for ensuring that medical and surgical instruments do not transmit microorganisms to patients. It is important that the HCP is able to identify, based on the items' intended use, what method of disinfection or sterilization is indicated. Ensure that all HCP who reprocess instruments have comprehensive training on reprocessing procedures and that they understand the importance of adhering to CDC guidelines.[7] A log of all HCP who are competent to reprocess instruments should be kept in the reprocessing area, identifying date of education and training and the name of the trainer.

Written policies for cleaning, sterilization, and disinfection in the office will help ensure that these procedures are performed properly. A copy of the manufacturer's recommendations for cleaning and disinfection of the instrument should be filed with the written policies and procedures. Regular reviews should be conducted to be sure that policies and procedures are being followed, monitored, and documented.[7]

Laundry Services

Laundry service needs are usually minimal in outpatient settings. Disposable exam gowns and drapes are often used. Develop policies and procedures addressing the handling, processing, and storage of clean and dirty linen wherever it is reused.[39,40](See **111. Healthcare Textile Services**.) Laundry handling practices that minimize agitation to prevent microbial aerosolization, appropriate hand hygiene, bagging soiled linen at the location of use, and separation and safe transport and storage of clean linen are components of these procedures.[2,39]

When a vendor provides laundry services, it is important to review the contract periodically and ensure that infection prevention policies and any regulatory requirements are met (e.g., water temperature), and that there is a protocol for follow-up of accidental exposure to sharps or bloodborne pathogens.

Occupational Health

Healthcare providers are frequently exposed to persons with communicable diseases. Additionally, healthcare providers can pose a risk to patients and other office staff if they have a communicable disease. Written policies should contain detailed criteria for exclusion from work, screening for TB, exposure to blood and body fluids protocol, and vaccinations of healthcare providers. (See Chapters 100 Occupational Health; 101 Occupational Exposure to Bloodborne Pathogens; and 103 Immunization of Healthcare Personnel.)

Construction, Renovation, and Water Damage

Outpatient building codes may not be able to meet the same strict infection prevention standards as hospitals. During planning for new construction or renovation, the IP can provide guidance and serve as a champion for inclusion of infection prevention design elements. Evaluate items such as: sink placement, type of sink, soap and towel and ABHR dispensers, floor coverings, adequate space and facilities for medication preparation and storage, including refrigerators/freezers, adequate space for and practical placement of storage, and instrument reprocessing. Consult the American Institute of Architects' *Guideline for Construction and Renovation in Healthcare Facilities*and state or local codes for healthcare buildings.

It is crucial that the IP be involved in the planning stages of a new facility. Depending on the services that the facility will provide, they will need to complete a risk assessment to determine the potential for exposure to an infectious patient or infectious substances during a procedure. This will determine whether specific items such as a negative pressure room, special air flow and handling, special scrub sinks, private bathrooms, and specific patient or staff traffic flow design will be required, and included in the building design.When the facility is completed, the IP should be involved in the commissioning process to make sure that critical infection prevention elements are installed and operational as planned. Pay careful attention to elements such as sinks, private bathrooms, and negative pressure rooms as these often get dropped from construction plans as cost saving measures.

Construction and renovation activities in preexisting and operational sites enhance the dispersal of microorganisms into the environment. Infection prevention and control risk assessment tools and guidelines are available and are aimed at mitigating this risk.This assessment should be performed before beginning any renovation or construction activity and should address barriers, traffic patterns, expected cleanup of the work site, air filtration needs, and disposal of any waste in a safe manner. Plan for, as much as possible, construction to occur during off hours to reduce dust exposure. The IP and

other HCP should know how to contact the construction supervisor in case there is dust or other problems and be empowered to shut down the construction or demolition if necessary.

For potential floods or water damage, develop procedures that include emergency contacts and maintenance service for remediation for the administrator or staff on-call, should a water damage situation occur during nonbusiness hours. (See **114. Heating, Ventilation, and Air Conditioning**; **115. Water Systems Issues and Prevention of Waterborne Infectious Diseases in Healthcare Facilities**; and **116. Construction and Renovation**.)

Emergency Planning and Disaster Management

Emergency planning is vital across all levels of healthcare. If a disaster or widespread outbreak was to occur, it is likely that initial cases will arrive at clinics—involving healthcare delivery locations across the continuum of care. Health systems with ambulatory care sites should include these sites in their emergency plans, with updates as changes occur. Independent outpatient settings need to coordinate emergency plans with the local hospitals, public health departments, and other government agencies.

To stay informed, IPs are encouraged to join email alert systems such as ProMed mail, a program of the International Society for Infectious Diseases for monitoring emerging diseases, and the state health department alert system and involve outpatient settings in participation in community disaster planning efforts. IPs can play a crucial role in ensuring that the emergency plan addresses the following issues specifically for ambulatory care:

- An administrative action list including key phone numbers (e.g., on-call administrators, local emergency department, microbiology laboratory, infection prevention) and emails for effective communication during the event and expectations for the outpatient site.
- A list of pertinent external agencies (e.g., law enforcement, public health) with phone numbers and circumstances for contacting them.
- A respiratory hygiene program for emergencies.
- A flow sheet for triaging patients who arrive on-site as well as telephone triage.
- Routine screening and assessment for patients with potentially highly communicable diseases and instructions on whom to call if there is a suspicion of one of these diseases. Include definitions and descriptions of high-risk syndromes/symptoms.
- Barriers, such as gowns and masks, are made available in case of emergency and a plan developed on how to restock these items during an emergency.
- An inventory list of gown, gloves, masks, respirators, waterless hand sanitizers, and other important equipment on hand.
- Procedures for acquiring and maintaining supplies of ABHR and bottled water in the event of loss of clean water for drinking and hand washing.
- Procedure for safe transfer of potentially infectious patients.
- Tracking exposures to other patients, visitors, or healthcare staff.
- A protocol to obtain vaccines, immunoglobulin, antibiotics, or antitoxin from health departments.
- A protocol for the efficient evaluation and release of patients, visitors, and healthcare staff.
- Clear instructions for the role of each ambulatory care site during an event. Will the site serve as a neighborhood alternative care site? Will the site close? Will the site continue to see noninfectious

patients? Does the site have air-handling systems such that it can serve as an "isolation" unit?

(See **119. Emergency Management**, and **120 Infectious Disease Disasters**.)

Specific Ambulatory Care Settings

This section summarizes the risk factors and setting-specific strategies for selected outpatient specialties. Endoscopy, ophthalmology, dialysis, and dentistry are covered in other chapters. Ambulatory surgery centers are addressed in **64. Ambulatory Surgery Centers**.

ALTERNATIVE MEDICINE

Alternative medicine has become part of primary care. Although the risk of infection in these procedures is low, HAIs have been reported.[42,43] Because the care provided is often very different from traditional Western medicine, there may also be varying views about traditional infection prevention. For these clinics, it is important to assess what practices, medications, equipment, or devices might have infection potential, and make recommendations accordingly. For example, if acupuncture is performed, it is important to make sure that disposable needles are discarded after each case. If massage is practiced, make sure that any cream or oil container is not dipped into with bare hands and there is no "double dipping" (i.e., accessing a multiuse container of massage cream with soiled hands). The preferred way to obtain product is to scoop out the needed amount for the patient onto a paper towel or napkin with a disposable spoon or tongue depressor.

INFUSION CENTERS

Patients receive infusion therapy most commonly because of cancer. Frequent hospitalizations, underlying disease, and/or chemotherapy treatments make these patients among the most immunocompromised in the healthcare system. They are at higher risk to be colonized or infected with MDROs, and among the most likely to develop *C. difficile* infection.

Practices to prevent bloodstream infections in ambulatory care settings are the same as those in acute care settings. (See **34. Intravascular Device Infection**.) Make sure that infusates are stored and prepared immediately before use according to strict pharmacy standards. Because the client cares for the intravascular device in the home setting, patient education including line care protocols is most important. Develop a method to track positive blood culture results as a mechanism to detect outbreaks or clusters. Ensure that CDC guidelines for prevention of infection are followed.[44]

Because patients who are treated in infusion centers may be at high risk for infections with MDROs and *C. difficile*, Standard Precautions and hand hygiene compliance should be monitored. Infusion chair, side table, and other surfaces of the infusion station or bay should be cleaned and disinfected with an EPA-approved cleaner-disinfectant after each patient. Gloves should be used for access of the intravenous (IV) site or contact with small wounds or mucous membranes. Gloves and gowns should be worn for contact with large wounds or leaking ostomy sites or bags. Ensure that patient bathrooms are cleaned and disinfected at least daily[1] and whenever contaminated with fecal material. Develop protocols for cleaning and disinfecting bedside commodes after each patient use and cleaning common areas, such as nourishment rooms, on a regular basis. (See the earlier part of this chapter for a general discussion on MDROs.)

Prevention of Airborne Disease

Develop policies for providing masks for infusion patients who present with signs and symptoms of respiratory illness. If the patient is severely immunocompromised, he/she may choose to wear a mask to prevent airborne exposure. This population is particularly vulnerable to airborne fungi released during construction. When there is construction, alert this population through signage or on electronic appointment sheets, and provide masks near entryways.

INTERNAL MEDICINE SPECIALTIES: CARDIOLOGY, PULMONARY, RADIOLOGY, AND RHEUMATOLOGY

These areas typically perform minimally invasive procedures; however, there are a few practices that create potential risks.

When stress testing is performed in cardiology, reusable facemasks must be reprocessed. If face masks touch only the skin around the mouth, they can be low-level disinfected.[7] However, if there is any risk of contacting the oral cavity or tongue, high-level disinfection is recommended.[7] Develop processes to ensure that ultrasound probes used on intact skin have received low-level disinfection between cases to reduce contamination.[45,46,47] (See **50. Cardiac Catheterization and Electrophysiology**.)

In pulmonary clinics, newer breathing test equipment is fitted with filters to prevent downstream contamination with organisms expelled during testing. When nose clips and mouthpieces are not disposable, disinfect according to standard guidelines. In geographic areas in which there is a risk of TB, clinicians should maintain a high index of suspicion and institute Airborne Precautions during diagnostic testing on high-risk patients, with arrangements to perform cough inducing procedures in a negative pressure room. HCP should wear an N95 respirator during cough-inducing procedures.

Outpatient radiology may perform ultrasonography; if vaginal ultrasounds are used, the probe must be high-level disinfected after each patient, even if a condom is used to cover the probe. When intact skin touches radiology machines, such as in mammography, surfaces require low level disinfection after each patient. Please note that nonsterile ultrasound gel is intended for external use only. Use of this product on mucous membranes has been associated with pseudo-outbreaks.[47]

Rheumatologists may perform steroid injections or use arthroscopes. Steroid injections have been associated with septic arthritis.[48,49] Develop processes to monitor injection practices for aseptic technique, storage, and preparation of the medication, and patient skin preparation (see Safe Infection Practices, described earlier in this chapter.)

OBSTETRICS, GYNECOLOGY, AND INFERTILITY

Many medical procedures are performed on an outpatient basis in this population, but there are few reports in the medical literature of infections. It is important to protect the pregnant patient from exposure to infectious diseases during her healthcare visits. Therefore, infection prevention centers on adequate reprocessing of instruments. Any instrument that contacts mucous membranes, including hysteroscopes, vaginal specula, and vaginal ultrasound probes, must be high-level disinfected.[7] Biopsy devices or other instruments that contact tissue through the vaginal or cervical wall need to be sterilized. In addition, the environmental surfaces potentially contaminated by vaginal or cervical secretions need to be cleaned and disinfected with an EPA-approved product.[7]

Infertility clinics that perform in vitro fertilization have specific recommendations from the American Society for Reproductive Medicine and are regulated by the U.S. Food and Drug Administration Human Cell, Tissues and Cellular and Tissue-Based Products (HCT/P). These recommendations are to protect the tissues and embryos from harm from chemicals as well as infectious agents. These procedures are typically performed in an operating-type room with specific air flow requirements.[50]

OTOLARYNGOLOGY/AUDIOLOGY

Potential risks in otolaryngology are related to use of endoscopes, both rigid and flexible, that enter the oral or nasal cavity and sinuses. Suctioning is common in these clinics; assure that the tubing and suction catheter is changed after each patient and that the suction canister is emptied on a regular basis. Review how anesthetic nasal sprays are handled. All labeling, mixing, expiration dating, and storage needs to be consistent with pharmacy policies and procedures. The delivery device must at least have a separate tip for each patient. It is preferable to use single-use devices to deliver the anesthetic.

Where swallowing studies are performed, ensure that reusable devices are high-level disinfected after each patient. Prepare any food or liquid used during the studies fresh for each patient; store food and monitor refrigerators according to institutional guidelines.

Audiology is also a low-risk area. Toys used during pediatric evaluations should be cleaned after each patient; avoid stuffed animals and cloth toys. If ear pieces are not disposable, they should be low-level disinfected after each patient.

PAIN CLINIC

Pain clinics in which anesthetics are injected into the spine or where fluoroscopy is used are set up similarly to an operating room. The major infection prevention implications are preventing organisms from entering the injection site during the procedure and making sure that reusable devices are cleaned and sterilized. The spinal site should be prepared similar to a surgical site. Anesthesiologists typically perform the procedures and need to follow strict aseptic technique for surgical hand scrub, sterile gloves, and garb as in the operating room for any procedure involving an incision. Injections, on the other hand, may be performed using sterile gloves with adequate hand hygiene and patient skin preparation. Assure that medications are labeled, mixed, dated, and stored consistent with pharmacy policies and procedures and that single-use dose vials are used only once.[51]

PLASTIC SURGERY AND WOUND CARE CLINICS

Plastic surgery and wound care clinics may perform a variety of procedures, including saline injections of breast implants; liposuction; minor plastic surgeries not requiring an operating room; removal of skin cancers; and debridement and other care techniques for large, nonhealing wounds and decubiti.

Risks for patients who have plastic surgery procedures are similar to surgery patients in general, but are generally much lower. The procedures are less invasive, shorter in length, and local anesthetic is frequently used. Of course, procedures for sterilization of surgical instruments are necessary. Adequate skin preparation for the patient, and surgical preparation for the surgeon, as well as strict aseptic technique, is essential. Preparation of saline for implants must occur aseptically, with a new bag of saline for each patient. Ensure that sterile trays are set up for each patient at the time needed using aseptic technique, and are not set up in advance of procedures.

Risks to wound care patients include transmission of infection or contamination of the environment from drainage from large wounds. Typically these patients are diabetic, paraplegic or quadriplegic, or have underlying conditions and extensive contact with healthcare facilities that put them at high risk for infection and colonization with MDROs. For these patients, it is essential to have stringent procedures in place for cleaning the treatment room after each procedure. In addition to the horizontal surfaces, include high-touch surfaces such as door, faucet, and cabinetry handles. Ensure that blood pressure cuffs and glucometers are cleaned and disinfected between patients. Institute procedures for cleaning and disinfecting any waiting room surface that is contaminated with uncontained drainage. HCP must practice Standard Precautions: hand hygiene, gloves, gowns, and face protection for potential splashing. [52]

The IP should develop a mechanism to track infections resulting from procedures in a surgery clinic or potential cross infection from the wound clinic.

PODIATRY SERVICES

Podiatry services are typically provided to geriatric or diabetic patients and are usually limited to nail cutting or removal, including ingrown toenails. The primary risk factors in this setting are inadequate reprocessing of clippers, scissors, and other equipment. After each patient use, thorough cleaning of equipment to remove all debris is essential. Items should then be sterilized or high-level disinfected.[7]

Diabetic foot ulcer care is often performed in outpatient podiatry. Use of an algorithm with specified prevention and treatment actions should be considered to reduce risk of adverse infectious outcomes.[53]

Onychomycosis (fungal infection of the nail) is prevalent in the geriatric and diabetic population.[53]

Concerns have been raised regarding the potential occupational hazards related to treating onychomycosis in the podiatric setting. The chronic exposure of staff to toenail dust generated by burring and drilling may lead to a variety of symptoms, such as conjunctivitis, rhinitis, asthma, coughing, hypersensitivity, and impaired lung function. Therefore, methods to minimize dust aerosolization should be used, including vacuum drills.[54,55]

A reporting mechanism to the IP should be developed for patients who return with an infection after a podiatry procedure.

PRESURGERY CLINICS

Some hospitals have set up screening clinics where all preoperative patients are seen for blood work, anesthesia evaluation, and preoperative teaching. Infection prevention needs to be part of the patient teaching, both verbally and with written instructions on these issues:

- Describe presurgery bathing, including when it is to be performed and with what product.
- Reinforce that smoking is a risk factor for postsurgery infections.
- Remind patients that they should not shave the site preoperatively, and explain what, if any, hair removal will be needed at the time of surgery.
- Outline measures patients can take to protect themselves postsurgically, such as deep breathing and coughing, ambulating, and encouraging healthcare providers and visitors to practice hand hygiene.
- Inform the patient who to call if they develop an infection (e.g., upper respiratory or urinary tract) before the surgery to determine if the surgery will need to be postponed.

- Outline signs and symptoms of postsurgical infection, and where to report if these occur.
- Review if prophylactic antibiotics will be administered and the role of antibiotics in surgical infection prevention.

If the patient has had an MRDO (by culture or by reliable history) and will be admitted at the time of surgery, ensure a system is in place to alert the operating suite or admissions for placement of the patient into contact precautions. Consider a decolonization procedure prior to surgery—including chlorhexidine baths and mupirocin nasal treatment. Newer technologies under development using photo-disinfection of the nasal cavity immediately prior to surgery have shown promising results in decreasing surgical site infections with MRSA.[56]

UROLOGY

The risks from cystoscopy and other procedures are generally urinary tract infection or bacteremia caused by colonization of the periurethral area and subsequent contamination of the bladder by the patient's own flora during the procedure.

Prevention of infection centers on effective reprocessing of equipment, such as cystoscopes and prostate biopsy equipment, and disposing of single patient use items after each case, such as IV bags of fluid and tubing. Because there have been anaphylaxis-like reactions associated with the use of ortho-phthalaldehyde disinfectant[7]for cystoscopes, ensure that other effective high-level disinfectants or sterilization processes are implemented.

PHYSICIANS' OFFICES

The design and layout of physicians' offices have important implications for infection prevention. There should be at least one examination/treatment room available for each physician/practitioner. Examination/treatment rooms should be a minimum floor space of 80 square feet. Furniture should be arranged to ensure at least 2 feet, 8 inches clearance at each side and the foot of the examination table.

Rooms used for minor surgical and cast procedures should have a minimum floor space of 120 square feet. Furniture in these rooms should be arranged to ensure at least 3 feet clearance at each side and foot of the treatment table.

Regardless of the purpose of the patient care room, each should have a hand cleaning station (with either ABHR or soap and water) and a separate counter for documentation. Faucet aerators are not recommended because of their association of contamination by *Pseudomonas*spp. and other bacteria.[40, 57]

There should be a room or designated area (depending on clinic size) for clean and sterile supplies and a separate one for the collection, storage, and disposal of soiled materials. Each of these rooms should have a hand cleaning station. There should also be a room containing a service sink to store all housekeeping equipment and supplies.[42]

A bathroom containing a sink should be positioned so that it is easily accessible from all patient care rooms. If the clinic has no more than three examination and/or treatment rooms, this bathroom may also serve the waiting area.[42]

Public areas include a reception desk and a client waiting area. Any toys or other materials used for diversion found in the waiting room should be able to withstand regular cleaning with hot water and detergent. Ideally, the waiting room will be large enough and arranged to allow for spatial segregation of patients suspected of having infectious illnesses. Hand hygiene stations should be highly visible and readily available for reception staff and patients. Depending on the size of the office and number of physicians who utilize the space, this may also include a bathroom with hand-washing facilities that is separate from patient care areas.

Conclusions

Ambulatory patient care is growing exponentially, as more and more procedures are being performed on an outpatient basis. In addition, many areas of hospitals, such as radiology and surgery, serve both inpatients and outpatients. The transmission of communicable diseases, especially by airborne or droplet spread, can be enhanced in this type of environment. Increased use of invasive devices and procedures increases the risk of infection from contact with contaminated equipment. Managing outpatient sites offers unique challenges and opportunities for infection prevention. Careful adherence to established infection prevention principles, adapted to the outpatient arena, will minimize infection risks to patients, staff, and family members/visitors. When outpatient settings are part of larger institutions, the goal is to integrate outpatient infection prevention and control with the institution as a whole.

A comprehensive infection prevention checklist designed for use in ambulatory care settings can be found at **http://www.cdc.gov/HAI/pdfs/guidelines/ambulatory-care-checklist-07-2011.pdf**.

Future Trends

ELECTRONIC MEDICAL RECORD TECHNOLOGY

As electronic medical records (EMRs) become more common and search engines more sophisticated, close to real time and increased record review is possible. This technology increases the ability to discover potential outbreaks or exposures and to set up syndromic surveillance. When outpatient records are available, it also increases the ability to detect surgical site infections or bloodstream infections, and thus to perform surveillance on outpatient procedures. Because of the rapid response time, it is possible to report back to the facility more quickly, allowing for a quicker response with interventions. (See **6. Healthcare Informatics and Information Technology**.)

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Behavioral Health

Author(s): Larysa M. Fedoriw, MPH
Healthcare Epidemiology and Infection Prevention

Northwestern Medicine
Chicago, IL

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Abstract

Infection prevention within the behavioral health setting is a diverse practice. Freestanding acute care hospitals, specialty psychiatric hospitals, substance abuse centers, outpatient practices, group homes, and correctional institutions are a few of the many environments in which an infection preventionist may find behavioral health-related infection prevention challenges. The infection preventionist is confronted with unique opportunities to identify, prevent, and control infection. Patients with mental illness may be at increased risk for infection in the community. The unique practices of the various treatment settings, as well as the behaviors of the clients themselves, can lead to a heightened risk for transmission to other clients and staff. No matter how challenges present themselves, the behavioral health infection preventionist's goal is to develop strategies designed to identify infections and prevent transmission.

Key Concepts

- Healthcare-associated infections in behavioral health are usually related to the human interactions of milieu therapy (e.g., upper respiratory tract infections because of client mingling), immune system suppression related to age, underlying medical conditions, or substance abuse.
- Healthcare-associated infections in behavioral health can increase both treatment costs and length of stay.
- Healthcare-associated infections in behavioral health can be reduced with effective infection prevention strategies, resulting in a decrease in both treatment costs and length of stay.
- Healthcare-associated infections in behavioral health are usually treated with topical or oral medications because providing intravenous therapies may be beyond the capabilities of the individual setting(s), in addition to posing a risk to clients' physical safety.

- Healthcare-associated infections in behavioral health most frequently occur in the eyes, ears, nose, throat, mouth, and upper respiratory tract; the next most common sites are skin and soft tissue.
- Infection prevention in behavioral health requires application of recommended prevention strategies to the extent possible. The unique behavioral traits of some clients may pose an obstacle to traditional methods.
- The adaptation of infection prevention to the behavioral health setting can be achieved by addressing the six links in the chain of infection: organism, reservoir, portal of exit, susceptible host, portal of entry, method of transmission.
- Clients should always be included in the plan of action to prevent or reduce healthcare-associated infection transmission to other clients through the development and use of behavioral contracts. A client may be persuaded to control undesirable behavior by signing a contract stating that, if the behavior continues or reemerges, certain consequences may be expected. For example, limiting time the client has with visitors or can engage in a favorite activity, can reinforce the client's sense of responsibility for his or her own behavior.

Background

The purpose of the behavioral health facility is the treatment and management of mental illness through the use of behavioral health modification, therapeutic processing, skill building, and psychotropic medication. According to the World Health Organization (WHO) Mental Health Gap Action Programme (mhGAP), lifetime prevalence rates of mental disorders in adults worldwide range from 12.2 to 48.6 percent, and 14 percent of the global burden of disease can be attributed to these disorders.[1]

Depression, anxiety, and other mental illnesses are major contributors to morbidity in the United States.[2,3] Untreated mental illness can have short-term and long-term adverse effects by bringing about poor health behaviors, diminished immune functioning, and negative disease outcomes, and they can produce increased societal costs.

Untreated, or undertreated, mental illness puts the patient at higher risk of infection because of risky behavior and an unsafe environment. Mental illness is closely associated with substance use and abuse.[4] The lifestyle of illicit drug users leads to higher rates of human immunodeficiency virus (HIV) infection, viral hepatitis, and sexually transmitted diseases.[5,6] Periodic homelessness is common, and lack of personal hygiene, poor nutrition, and exposure to the elements in homeless persons contribute to susceptibility to infection. Communicable diseases such as lice, scabies, and skin diseases are found frequently in homeless persons. Cramped living conditions found in shelters are a risk factor for respiratory disease, such as tuberculosis (TB).[7,8,9] Homeless individuals presenting to emergency departments have a higher prevalence of mental illness than those that are not homeless.[10] The Department of Health and Human Services estimated that in 2010, 26.2 percent of homeless persons on any given night had a severe mental illness, and 34.7 percent had chronic substance abuse problems.[11] Clearly, as mentally ill persons are admitted into the healthcare system, the infection preventionist (IP) is faced with the challenge of identifying and controlling communicable diseases in an at-risk population.

Certainly not all behavioral health clients are severely mentally impaired or homeless, but those with mental illness have a high risk for infection because of impaired judgment, poor impulse control, reduced self-care, irregular or poor medication compliance, lack of personal hygiene, poor nutrition,

exposure to extreme weather, and lack of health or dental care. Risk-associated behaviors that may be encountered are alcohol and drug abuse, self-inflicted injury, violence, and sexual encounters that may even occur while in treatment. The quality of medical treatment is compromised for those with mental illness because they frequently use emergency services rather than seek preventative medical care.

Financial, geographic, and cultural obstacles also contribute to undertreatment of physical health in clients with mental illness.[12] Those treated, also referred to as clients or residents, come into treatment from all socioeconomic environments. There are many modes of therapeutic interventions. Mental health clients may be found in acute care hospitals; psychiatric hospitals; or alternative settings such as long-term care facilities, ranches or farms, group homes, or dormitory-like treatment facilities, many of which specialize in treating addictions. Other facilities provide mental health services in fluctuating increments of time. Examples of these services are shelters for the homeless, supervised or transitional living, crisis stabilization centers, therapeutic foster care, partial hospitalization (e.g., day treatment, adult day care, and intensive outpatient), and vocational rehabilitation.

Correctional facilities have a high burden of mental illness. According to the U.S. Department of Justice, more than half of prison and jail inmates had a mental health problem at midyear 2005, and a greater percentage of inmates with mental problems also abused drugs and alcohol compared with inmates without mental problems.[13] The prevalence of HIV, methicillin-resistant *Staphylococcus aureus* (MRSA), and other infectious diseases is higher in prisons than in the general population, and unmet medical care, deficiencies in screening, and close living conditions all foster disease burden and transmission.[14,15,16] In addition, individuals who have mental illness are more likely to be homeless prior to incarceration. As a result, those with mental illness who acquire infectious diseases while incarcerated may introduce those diseases to the mental health system following release.

Because of the structure of treatment offered, many facilities are not able to collect information for healthcare-associated infections (HAIs) that can be reported externally. However, this does not mean the data cannot, or should not, be collected and reported internally. The data collected may be analyzed and transformed into meaningful information. This information becomes a valuable tool for performance improvement and systems development.[17,18]

This chapter provides guidance to the IP in developing an infection prevention system specific to the behavioral health setting. References and supplemental resources are itemized at the end of the chapter; however, the list is not exhaustive. Networking with local and national infection control professionals in behavioral health should also be considered an important resource.

Basic Principles

- Mental illness is a condition that is chronic or severe and involves one or more of the following characteristics: emotional, cognitive, or physical distress; inability to experience positive emotions, cognitions, or physical pleasure; inability to function occupationally, relationally, or recreationally in ways that contribute to a sense of satisfaction or well-being; behaviors that lead to physical impairment to one's self; behaviors that lead others to experience physical, cognitive, or emotional pain; and an inability to connect with others in mutually supportive and beneficial relationships and to maintain this type of relationship.
- Behavioral healthcare provides prevention, intervention, and treatment services in the areas of mental health, substance abuse, and developmental disabilities.

- An HAI is any infection or infestation, preventable or nonpreventable, that occurs because of facility-related care delivery while a client (also referred to as resident or inmate) is in the care of the facility.
- A community-acquired infection is any infection or infestation that is present or incubating at the time of admission, or to which the client was exposed on an outing, during treatment at a different facility or office, or while on a pass/leave of absence, including those infections that are chronic, recurrent, or the result of noncompliance with medical therapy.
- Milieu is the social setting of a mental health client. A milieu infection is an infection that occurs after admission to the facility and as a result of client injury by a peer or self-injury (self-cutting; self-piercing; self-burn; unauthorized removal of sutures or staples or other therapeutic device; compulsive picking, scratching, rubbing, or washing; or banging of head, fist, foot, or other body part).

Infection Prevention in Behavioral Health

The behavioral health IP may need to develop or evaluate and update an existing infection prevention program. The IP must identify components that are necessary to an effective program and continuously evaluate the program for its effectiveness, efficiency, efficacy, appropriateness, and customer satisfaction.[19,20]The IP must scrutinize policies, procedures, and protocols and update them within prespecified time periods. The practice of infection prevention is not performed in a vacuum; therefore, many departments and disciplines will be involved in the system. Communication among all departments and disciplines is essential to a well-managed system.

AUTHORITY AND REPORTING RELATIONSHIPS

Authority

The IP should have the authority to safely place and remove clients who require isolation precautions based on infection and/or risk status. To facilitate this, the IP, in conjunction with unit/facility behavioral health staff, should determine the need to physically separate clients from the greater group, evaluate behavioral needs versus medical needs, and transfer clients with overriding medical needs to other units or other facilities with more appropriate isolation precautions capabilities. This authority should be clearly outlined by the facility executive and medical staff and can be reflected in policies, procedures, scope of service, or job description.

The scope of the infection prevention program is often dictated by the accreditation agency's requirements. The IP is responsible for the interpretation and application of these requirements along with state, federal, provincial, or other jurisdictional regulations as they apply to the facility.[21,22]The IP should use state, federal, and accreditating agency requirements as a base upon which to build the system and to win the support of the agency's authority.

Reporting

The IP has the following reporting responsibilities:

- Identify the reporting structure in the facility. It is essential to have the support and cooperation of administration, and reporting relationships is an important component in the infection prevention program.
- Report infection rates to the infection prevention committee or other supporting groups and committees and share data with hospital/facility leadership and administration.[23]

- Submit a year-end report that provides an overview of statistics, initiatives, cost-risk analysis, risk management/quality assurance initiatives, outbreak data, and special issues that have been addressed in the previous year. The report not only will highlight areas of achievement and opportunities for improvement but also will assist in keeping the program visible to those in authority who are responsible for support and funding.[23]

Another important reporting relationship exists between the IP and the local health authority. The IP contacts the local health authority to obtain a current list of reportable diseases and acquire forms for reporting. The local health department is an invaluable aid in the management of outbreaks when they occur.

Committees

Identify all committees within the organization in which it would be beneficial for infection prevention to take an active role. The IP often serves on committees such as the environment of care (EOC) committee or occupational safety and health committee. Pertinent information may be disseminated through these committees, making membership practical and expedient.

The Behavioral Health Infection Preventionist

The behavioral health IP may fill other roles within the facility—for example, as an employee health nurse, staff nurse, supervisor, safety officer, or staff educator, among others. High visibility in the practice setting will help to identify and address issues as they arise and allow staff members to be comfortable in sharing concerns. With experience, the IP will acquire the ability to be assertive, yet diplomatic, in situations in which the safety and well-being of clients, visitors, students, and staff are at risk.

The novice to behavioral health infection prevention should seek education that will provide an understanding of the principles of infection prevention and the transmission of infectious disease. Educational requirements may be outlined in the job description. The basic science of infection prevention and epidemiology is the same, regardless of the type of institution. Adequate training is required and supported by accrediting agencies such as The Joint Commission.[22]In addition, the IP in a behavioral health facility or in an inclient psychiatric unit within a larger hospital should seek education on mental illness, including the behaviors that increase transmission within the facility and in the community.

Continuing education allows the professional to stay current on emerging issues. Annual attendance at either local or national conferences should be a requirement and may be included in the job description. Courses in adult education may assist the IP in the presentation of new ideas to staff members. This *APIC Text of Infection Control and Epidemiology*offers the most concise information in infection prevention and supplements other formal training that can be obtained using the following resources:

- National and local Association for Professionals in Infection Control and Epidemiology (APIC) or Infection Prevention and Control (IPAC) Canada (formerly Community and Hospital Infection Control Association–Canada [CHICA]) courses
- Society for Healthcare Epidemiology of America (SHEA) and Centers for Disease Control and Prevention (CDC) courses
- Local, state, or provincial departments of health
- Universities and other academic institutions

- Local microbiology and infection prevention organizations
- Private consultants
- APIC, CDC, and SHEA online

Joining the local APIC or IPAC chapter will provide opportunities for networking and consultation. Chapter members may not always have similar facilities but can offer valuable guidance at many levels. A wealth of information from professionals across the country can be accessed through the APIC website. (See Supplemental Resources.)

Certification in infection prevention is encouraged and is an important step in personal growth and professional development.[24]Information regarding the requirements for Certification in Infection Control (CIC) is available on the websites of APIC and the Certification Board of Infection Control (CBIC).[25]

PROGRAM MANAGEMENT

Prioritize tasks and maintain separate time for infection prevention, especially if time is shared with another position. Manage time to include the key components of infection prevention.[26]

Infection Control Committee

The purpose of the infection control committee (ICC) is to advocate the prevention and control of infections within the facility. Although not all accrediting organizations require an ICC or alternative hospital committee, its function as the central decision- and policy-making body for all infection prevention issues and policies is essential. In the behavioral health setting, it is common for the ICC components to occur within the context of the EOC committee, safety committee, quality committee, or risk management committee.[15]

Policies and Procedures

Behavioral healthcare is highly regulated by governmental agencies, and policies must reflect the facility's intent to adhere to these regulations.[22]

References to policies and procedures regarding Standard Precautions, bloodborne pathogens, employee health, cleaning and disinfection, and other policies pertinent to any healthcare facility may be found throughout *APIC Text of Infection Control and Epidemiology*. To further develop the behavioral health facility's policies and procedures, state, federal, provincial, or other jurisdictional regulations and licensing requirements should be referenced, and policies to meet needs should be implemented. The policies regarding child protective services, TB skin testing of employees and clients, and issues regarding client rights and confidentiality as mandated in the Healthcare Insurance Portability and Accountability Act are stringent in behavioral healthcare.

The Occupational Safety and Health Administration (OSHA) mandates a separate policy regarding control of exposures to bloodborne pathogens and TB.[27,28,29]

Exposure Control Policy

Occupational exposure is covered in **101. Occupational Exposure to Bloodborne Pathogens**, **104. Pregnant Healthcare Personnel**, and **105. Minimizing Exposure to Blood and Body Fluids**. When evaluating the exposure risk of employees, consider the duties performed that may place the individual at risk. Licensure does not automatically put the individual at a higher risk (e.g., an environmental

services worker is considered at greater risk for exposure than a physician). The use of engineered safety device syringes and needles to sedate clients while physically restraining them (therapeutic hold) or to vaccinate a client is essential in behavioral healthcare. Following OSHA guidelines, the IP must institute a program to evaluate, select, and provide engineered safety devices for staff.[28] Personal protective equipment (PPE)—including masks, gloves, gowns, bite gloves, spill kits used to remove and disinfect an area in which a spill or splash of blood or other potentially infectious material has occurred, and Plexiglas riot shields used in correctional facilities—should be addressed in the exposure control plan.

Employee post-exposure prophylaxis and follow-up must be addressed. Steps to take in the event of an exposure should be defined:

- Name the responsible party to direct the care of the employee and source client in the absence of the IP.
- Designate where the employee(s) will be sent for testing.
- Itemize the information to be provided to ensure appropriate assessment of the exposure and risk.

If care is outsourced, the receiving agency will be responsible for reporting on the care and follow-up of the employee. All exposures should be analyzed and opportunities for improvement should be implemented.

Tuberculosis Control Program

The behavioral health setting is at high risk for clients with TB.[29] When ordered, TB screening should be performed on all new admissions using a TB skin test (TST), serology, or medical evaluation, as outlined in the CDC's "Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care settings, 2005."[30] Two-step TST also may be required, in accordance with state, local, or other governmental regulation. The licensing authority for the facility dictates employee testing; however, annual TB risk assessments of the facility may identify problem areas that would indicate more frequent testing. Because most behavioral health facilities do not have x-ray capabilities or negative airflow rooms, isolation precautions of the client suspected of having active TB must be addressed until transport to another facility can occur. The IP should outline the procedure to transport the client to an appropriate facility in a manner that will protect other clients and staff from exposure.[30,31,32,33] Placing a surgical mask on the client serves to protect others in the environment from TB.

Developing the Infection Prevention System

To develop a comprehensive system and determine surveillance targets, it is necessary to identify risk factors specific to the facility. The IP should evaluate the client population served, recognize risk behaviors of mentally ill patients, be acquainted with the treatment modalities that are offered in the facility, and identify any physical eccentricities of the property (e.g., facility is located in an area with ponds or lakes that may harbor disease vectors). In addition, recognizing health risks present in the surrounding community will help identify areas of special concern for clients.

Facilities serving children should address the risk of the transmission of childhood diseases by implementing an immunization-screening program for clients and staff.[34,35] Reviewing immunization records and providing for vaccination, if needed, are of particular importance in residential programs or if a child has an extended stay in an acute psychiatric setting. All employees should be aware of their immune status and should practice Standard Precautions and safe work practices. A policy should be in

place that reviews the vaccination or immune status of employees who work with children and that addresses provisions for vaccination when warranted. The importance of immunity for employees working in pediatrics and employees who are pregnant or of child-bearing age should be emphasized. In addition, an inpatient influenza and pneumococcal immunization program should be considered for adult clients.[36]

Identifying HAIs in the behavioral health setting is challenging in large part because HAI definitions created for the acute care settings may not be applicable. Many IPs find that the definitions for HAIs used in long-term care are most appropriate. These can be found in **61. Long-Term Care**. However, until definitions specific to behavioral health are established, the behavioral healthcare IP may use whichever published definitions most closely fit the practice setting. If targeted surveillance (where the focus is on specific events, infections, or client groups), rather than whole-house surveillance is used in the facility, the unique behaviors and needs of the individual population should be considered to determine risk. Surveillance should be focused on areas that represent the most serious negative outcomes to the client population.

Important information can be solicited during the intake history and physical. TB risk factors, recent hospitalizations, procedures that may place the client at greater risk for infection, and/or history of multidrug-resistant organism infections should be elicited. A travel history may indicate the possibility of exposure to serious respiratory infections such as avian influenza and Middle East respiratory syndrome coronavirus (MERS-CoV), West Nile virus, or Lyme disease. When possible, a computer alert system that tracks repeat admissions for clients who have been identified with drug-resistant infections is valuable. The information allows admitting staff to evaluate room availability and client needs that may be beyond the scope of care the facility can provide. The IP should have input into intake questions that may help identify risk for currently circulating community-acquired infection.

If appropriate to the facility, an educational program may encourage clients to practice sexual abstinence.[37,38] A procedure to address exposure to sexually transmitted diseases and bloodborne pathogens should be developed if sexual encounters do occur. It has been suggested that, in some cases, a facility may consider the availability of condoms for client safety.[39] However, based on the client's psychiatric diagnosis, clients might be unable to make reasonable decisions regarding sexual activity. To address legal implications and to investigate whether the sexual contact was consensual or nonconsensual, risk management and legal departments in the facility must be informed.

The IP should become acquainted with local authorities and encourage communication regarding bioterrorism, natural disasters, or outbreaks of communicable diseases. Facility management should determine the extent of facility involvement in the community's disaster planning.[40,41] A major role of the behavioral health facility during a disaster is surge capacity. The IP should address components of overcrowding, bed and client placement, and the spread of communicable diseases common to specific bioterrorism or natural disasters. They should also provide guidelines for transfer of affected clients and staff to a medical facility. Guidelines should include (1) a discussion of signs and symptoms of agents of bioterrorism and radiation exposure; (2) a listing of anticipated infections resulting from a natural disaster, including waterborne and foodborne illnesses; (3) recommendation for notification of the accepting facility; and (4) a recommendation for type of isolation precautions prior to and during transfer based on symptoms. The capabilities of the physical facility should be clearly outlined, noting any negative-pressure areas, private rooms, and other aspects of the building that may need to be readily available for client placement or influx.

Special Considerations for Psychiatric Clients

Engaging the client in his or her own physical health while in treatment is critical. As much as possible, clients should be made to feel that they are partners in their own treatment and to be aware of the behaviors that could facilitate infectious disease transmission. Guidelines for personal hygiene behaviors such as showering and wearing clean clothing, and demonstrations on hand and respiratory hygiene, can minimize the need for greater infection prevention precautions.

Hand hygiene is essential to prevent and control infectious disease transmission, especially in a setting where clients mingle in common areas; however, the availability of alcohol hand gel in a psychiatric setting may present significant risk for the clients. One concern is that clients with a history of substance abuse or self-harm may ingest the alcohol gel. Because of this risk, access to alcohol gel for hand hygiene must be strictly monitored. A demonstration of appropriate hand hygiene using soap and water can be provided for clients upon admission and on an ongoing basis. Use of bar soap should be prohibited due to the risk of microbial growth.

In some residential facilities, two or more clients may share a community bathroom. Clients can be provided with a caddy or basket in which to keep personal toiletry items. This practice not only reduces the risk of transmission of pathogens from personal items such as bathing sponges, but also provides for a clutter-free shower that enables housekeeping to effectively clean and disinfect. In addition, nonskid shower flooring helps to avoid slips and falls. Disposable paper mats for individual use protect the client from transmission of athlete's foot (tinea pedis). For safety reasons and to decrease the risk of an exposure to blood, disposable razors for shaving should be provided and discarded after use in an appropriate sharps container. Clients should be observed while shaving. Alternatively, a sign-out sheet can be used to ensure that clients do not harm themselves or others with the razor. If electric shavers are provided by the facility, a protocol for the cleaning and disinfecting of the shaver after each use is needed.

Many behavioral health treatment settings provide meals for clients in a dining room or other group room, increasing the risk of transmission of pathogens via the oral route. Clients should be instructed in hand hygiene and respiratory etiquette. Upon entry and exit from the dining room, clients should be encouraged to perform hand hygiene. Cough and sneeze etiquette should be encouraged to avoid dispersal of pathogens onto food or utensils. Common snacks, such as fruit that could be touched by many clients, should be washed by the individual prior to eating.

Most residential programs stress client self-reliance and self-care. As one facet of this, clients may be responsible for their personal laundry. Because of self-harm issues, water temperature in the laundry area may be kept below 120ºF (49°C).[42]Check local regulations for guidelines on water temperatures. An appropriate detergent for cold-water use should be used. Because of the risk of self-harm, detergent and softeners should be stored in a location that is not accessible to clients unless they are supervised. Mixing of client clothing should be prevented, and special consideration should be given to clients with incontinence, wound infections, skin lesions, and suspected or confirmed cases of scabies. In such cases, clothing should be cleaned using bleach in the wash water and dried on the hottest setting, and the washer and dryer should be decontaminated after each use. If bed bugs or other insects are seen on a client's clothing or bedding, the belongings of the client should be laundered or disposed of in accordance with recommended practice.[43]

Behavioral health clients are more likely to be outdoors than are acute care clients. At times of the year when risk for specific disease is known to be high in the community, the IP should alert staff members to the increased risk and make them aware of signs and symptoms and preventive measures to avoid

exposure. If there is a current risk of exposure to vector-borne diseases such as West Nile virus or Lyme disease, staff members should be recruited to observe for signs and symptoms of exposure as well as possible breeding sites for mosquitoes or ticks.[44,45,46,47] These measures should be applicable to the setting of the facility, in addition to the age and general health of the client population. Preventive activities, such as avoiding outings after dusk, use of an appropriate insect repellent, and the wearing of appropriate clothing for the setting, should be highlighted. There may be times during outbreaks in the community when client contact with the community, including a client's visitors, is limited or prohibited. Clearly establishing surveillance definitions can help facilitate accurate trending.

Environmental surveillance culturing is not routinely recommended, except in the event of epidemiologically significant outbreaks.[48] In some jurisdictions, routine culturing of water for the identification of *Legionella* is recommended. If culturing is recommended, an action plan should be developed in the event *Legionella* is identified.[49,50,51,52] For all laboratory testing of samples, when there is no on-site laboratory and specimens require immediate transportation not provided by a contract laboratory, a policy for the transport of specimens by nonhospital personnel must be provided that references both handling and transportation.

Self-inflicted injury as well as injuries caused by a peer while in a treatment setting may require prophylactic or empirical treatment with antibiotics. Use of antibiotics in a behavioral health setting may approximate the prophylactic or empirical approach common in a physician's office, rather than the therapeutic use based on culture results and radiological findings commonly found in the acute medical hospital setting.

In behavioral health facilities, the strictest of standards will apply to electroconvulsive therapy. Issues that should be covered in a guideline include PPE,[27,53] hand hygiene procedures,[54,55] healthcare personnel health, clients with communicable diseases, issues related to the use of multidose vials, and the cleaning and disinfection of equipment (such as electrode wires) and the environment[48] between clients. Reusable items such as bite blocks and laryngoscope blades require high-level disinfection. The practice of high-level disinfection necessitates maintaining chemical sterilization logs, providing eyewash stations, and adherence to current guidelines related to staff safety when using disinfectants.[56] A policy for the cleaning and disinfection of anesthesia machines may be obtained from the manufacturer. The IP should explore whether the appropriate disinfection can be performed within the individual facility or if it should be an outsourced service.

Policies and procedures should be developed for specific situations more likely to occur in a behavioral health setting. For instance, a policy may be necessary for identification and management of pediculosis and scabies, including monitoring for transmission, treatment (include staff monitoring of application of treatment) and follow-up; handling of laundry; and housekeeping procedures. The IP should develop guidelines for cleaning and decontamination of surfaces, personal and community items, and therapeutic items such as stuffed animals. The guidelines should also include exercise equipment such as floor exercise mats and swimming pool chlorination and cleaning.[48] Programs such as pet therapy, physical therapy, vocational therapy, and classrooms for school-aged children or adolescents all require policies to address infection risks and cleaning protocols (see individual chapters in this *APIC Text* for more information). Immunizations and health checks for animals used in pet therapy and for service animals may need to be included.

Isolation Precaution Considerations

The IP should develop a policy following CDC guidelines for isolation precautions. The policy should outline notification, immediate actions to take, location of isolation precautions PPE, and the types of isolation precautions that can be maintained in the facility and how clients should be handled in the event transfers are needed.[31]

For example, if the facility does not have a negative air pressure room for the containment of TB, state that airborne isolation precautions are not an aspect of the facility and outline the procedure for transport of the client to an appropriate facility. Include client and staff safety measures and required PPE. In addition, describe the post-exposure follow-up for employees. Refer to the current Healthcare Infection Control Practices Advisory Committee (HICPAC) guidelines for isolation precautions.[31]

Instituting isolation precautions of highly transmissible pathogens (i.e., *Clostridium difficile*) is a challenge in the behavioral healthcare setting. CDC and SHEA recommendations should be incorporated to provide guidelines for the facility. These recommendations can be found on the CDC website and the SHEA website. (See Supplemental Resources.) The *APIC Guide to the elimination of* Clostridium difficile t*ransmission in healthcare settings*is available from APIC and provides in-depth information regarding identification and prevention of *C. difficile*applicable to all healthcare settings.

Isolation precaution practices should follow epidemiologically sound principles based on transmission. However, these are not easily enforced in the behavioral healthcare setting. Cohorting of clients with the same organism (i.e., respiratory viruses[57]) is one solution. To control an infectious disease outbreak in a psychiatric unit, closing the unit may be necessary. The IP should make this decision in conjunction with leadership and unit staff, taking into account the transmission and course of the specific disease.

The need for room isolation precautions should be carefully considered and used judiciously. Isolation precautions deprive the client of valuable group therapy, skill building, and a sense of belonging. Isolation precautions disrupt a client's routine and may result in the removal of familiar objects. The effects of physical isolation precautions may include depression and anger, and the stigma of the diagnosis of an infectious disease can cause the client to feel dirty or unclean.[58,59]However, the needs of a single client must be weighed against those of the greater group that could come into contact with the client, directly or indirectly. If the client's behavior or health status poses a significant risk of disease transmission, room isolation precautions may be necessary and appropriate. Measures should be taken to continue the client's psychiatric treatment as extensively as possible.

Regardless of the facility type, if the client is to be admitted with a known communicable disease, the following questions should be addressed: Do the client's medical needs outweigh the client's psychological needs? Can the facility provide the care and staffing the client requires? Can the facility provide the expanded precautions (isolation precautions) needed for the organism? Will admitting this client place staff and existing clients at increased risk due to the nature of the facility and its ability to care for the clients?

Scenario I (a)

Problem

A client with varicella, or a recent exposure to varicella, without prior disease or vaccination, is scheduled for admission for medication evaluation.

Solution

This admission should be delayed until the incubation period has passed or the disease has reached a point in illness resolution at which transmission is not a risk. It is important to consider that the client may be infectious 48 hours prior to onset of symptoms. The nonimmune, exposed client may be given varicella vaccine and possibly varicella-zoster immune globulin.

Scenario I (b)

Problem

The same client from Scenario I (a) is an emergency admission and there is no negative airflow room or freestanding, high-efficiency particulate air (HEPA) filtering unit.

Solution

Consider recommending transfer of this client to a medical/psychiatric unit with a negative pressure room that provides less risk to healthcare personnel while meeting the psychological needs of the client. Maintain a list that identifies exposed nonimmune healthcare personnel as well as other clients. Explore the feasibility of making a line listing that identifies potentially exposed clients and healthcare personnel until the ill client is transferred. If it becomes necessary to notify discharged clients and off-duty staff, a solid list of potential exposures will help to expedite notification.

Scenario I (c)

Problem

The same client from Scenario I (a) is already in the facility and develops varicella.

Solution

Initiate Airborne Precautions by placing the client in a negative pressure room and Contact Precautions. In the absence of a negative pressure room, and in situations in which the client cannot be transferred to a facility with appropriate isolation precautions or be safely discharged, initiate other protective measures that are available. If the facility has a HEPA unit, place it in the client's room. Attempt to have the client stay in his or her room during the infectious state. Identify susceptible staff and clients. The administration of varicella-zoster immune globulin for susceptible individuals should be considered if they meet the criteria. Following CDC recommendations for occupational health, all healthcare personnel should have been screened for a history of varicella. Staff with an unknown history should have titers drawn upon employment, and those with a negative or unknown history should be immunized or offered immunization. Susceptible individuals should be considered to be infectious for 10 to 21 days after exposure. Staff members who refuse vaccination or who are unable to be vaccinated should be furloughed during this period. The administration of varicella-zoster immune globulin prolongs this period to 28 days.

Contact Precautions are applied when the client is in his or her room and the client environment is considered as an extension of the client. When an employee enters the client's room, Contact Precautions should be enforced (some clients deliberately contaminate the environment); when the client lies down on his or her bed, otherwise clean clothing becomes contaminated. If the client needs to come out of the room, have him or her wear a clean gown covering clothing and nonscabbed lesions and a face mask. Minimize the client's ability to come into contact with other nonimmune clients to the extent possible. If contact is unavoidable, mask clients who are susceptible (when possible), attempt to maintain a distance of 3 feet or more between clients, and prevent physical contact.

Scenario II

Problem

A client arrives in the emergency area with suicidal ideation and a plan. The client has MRSA colonization in his or her nares noted in the record of a previous medical hospital admission. The client was treated but has no follow-up cultures, no respiratory symptoms, and is able to follow directions. Is the client in danger of harming himself or herself or others if not admitted?

Solution

This client should be admitted due to the seriousness of the client's psychological situation. Because of his or her ability to follow directions, the absence of respiratory symptoms, and the previous administration of treatment, the client poses a decreased risk to the milieu. If the client is not displaying active infection or respiratory symptoms, no mask is necessary when leaving the room. Hand washing and the use of alcohol-free hand gel products (the client may use a waterless product under the supervision of staff) should be monitored. The client should use appropriate respiratory hygiene, which involves covering the mouth and nose when coughing, using tissues, and using a hands-free tissue disposal method whenever possible. The client may participate in the milieu, including groups. Occupational therapy activities should be restricted to individual activities, such as painting or beadwork, and the client's supplies and projects should be for the client's use only to avoid contaminating other client supplies. Large-group activities, such as throwing a ball between clients, should be avoided when possible.

Scenario III

Problem

A medical hospital wants to transfer a client who has been medically cleared from an overdose. While at the medical hospital, the client was identified to have vancomycin-resistant *Enterococcus*in his or her stool. The client is incontinent of urine and feces and also smears feces. Because of the client's psychotic state, he or she is unable to follow directions. What infection exposure risk will this client pose on the milieu?

Solution

This client is a risk to the other clients in the facility but should not, and in many areas cannot, be refused admission based only on current infectious disease status. This client will require one-on-one care for constant redirection. Can adequate staffing be provided? Will the client share a bath with other residents? Is a private room with private bathroom available for this client? If a bed can be blocked, but a private bathroom is not available, this client should not be admitted.

The situation poses an ethical dilemma. The client is not yet a client of the facility, and there are many clients entrusted to the facility's care who may be placed at risk if adequate housing and staff cannot be provided to care for the transfer. The client's psychological needs also must be met. If the facility is a psychiatric freestanding hospital or a psychiatric unit within a medical hospital, admit this client. Before the client's admission, address the staffing and room requirement needs.

Scenario IV

Problem

A female client is admitted with depression, suicidal ideation, and self-inflicted wounds. The client has a diagnosis of factitious disorder. She is admitted with draining wounds. The wounds are cultured, antibiotics are prescribed, and dressing changes are ordered. The client's wounds are covered, and drainage is adequately controlled. She is placed on contact isolation precautions and participates in the milieu. The client constantly manipulates the wound and does not practice good hygiene. Three days after admission, the wound culture returns positive for MRSA. The client is observed touching the wound and then touching items in the common area. Will this client's behavior allow her to continue to participate in the milieu?

Solution

The client should remain on contact isolation precautions. Because the client is constantly manipulating the wound and contaminating her environment, she should be restricted to her room. She may not participate in the milieu because of her behavior.

SURVEILLANCE

Surveillance in the behavioral healthcare setting is difficult. Guidelines outlined in **11. Surveillance**, should be followed. The IP must be innovative in applying suggestions in this chapter if they are appropriate to the facility. Surveillance in group homes and outpatient settings may not be possible.[60,61]

A surveillance plan for other settings (e.g., inpatient, residential) should be developed to provide an overview of the types of activities that will be conducted to provide a safe environment for clients and staff. List the types of monitoring and detail information to be evaluated. Useful methods to employ in data collection are as follows:

- During surveillance rounds, talk to staff and review charts and vital signs boards.
- Review laboratory values, culture and sensitivity reports, and chest x-ray reports to identify pneumonias and upper respiratory infections.
- Review pharmacy antibiotic reports to help identify possible infections by reviewing the indication for the order of an antibiotic whether empiric, prophylactic, or pathogen directed.
- Develop a method for staff to report possible infections to the IP, such as the use of a "bug board" (a place for staff to record possible infections for the IP to review), an email notification or a faxed report of a suspected infection from the unit to the IP, use of infection prevention liaison staff, or a protocol for telephone reporting.
- Review employee health trends with regard to exposures, health screens, and self-reported infections.

The IP must develop a plan to collect data and perform infection data analysis, identify outbreaks, and control and evaluate endemic problems (including the problem, interventions, improvements, and continued needs). The IP should develop benchmarks for HAI using the surveillance from the prior 24 months for the facility.

EMPLOYEE HEALTH/OCCUPATIONAL HEALTH AND EDUCATION

The IP is involved with employee health and may often be the employee health nurse. In many behavioral healthcare facilities, both clients and staff wear street clothing rather than traditional hospital gowns and uniforms. Although the client may appear thin or pale, other signs of infirmity, such as dressed wounds or intravenous lines, are often absent. There may be a high rate of turnover in staff. Combine these elements, and staff may forget or become lax about the unseen diseases the client may have. Standard Precautions should be used with all clients at all times. Staff should be provided with PPE, such as bite gloves, cardiopulmonary resuscitation masks, spill kits to clean up small spills and

splashes of blood or other potentially infectious materials, and gloves. Pocket-sized containers of antiseptic hand gel should be readily available to staff, with the knowledge that the odor of some of these products increases alcohol cravings in clients who are detoxifying from alcohol and that the containers may be taken by clients experiencing withdrawal or wanting to harm themselves.[62] Nonlatex gloves should be provided for employees who are sensitive to or allergic to latex.[63,64] The goal is the prevention of touch transmission by wearing PPE and focusing on contact with any moist body substance, mucous membrane, body tissue, and nonintact or flaking skin. The addition of respiratory hygiene to Standard Precautions is important in the behavioral healthcare setting. Staff should be taught hands-free hygiene for coughs and sneezes (coughing into the sleeve or use of tissue). At hire and annually, inservice programs should be provided for employees regarding Standard Precautions, the CDC hand hygiene guidelines, bloodborne pathogen exposure control plan, and TB control plan. The presentation should be focused on the audience being served. Some employees may not be familiar with medical terminology and should be addressed in terms that make the information understandable to them. Information also should be presented so that it is specific to the duties of the employees or department being addressed. Direct observation of staff work habits can provide the opportunity for on-the-spot training when Standard Precautions are not followed.

Employee health guidelines must be provided for the facility. These should address the requirements for health screens, tuberculin skin testing, medical illness leaves, and reporting of communicable diseases, such as varicella, influenza, norovirus, and conjunctivitis. Guidelines should include a protocol for post-exposure prophylaxis and should address issues regarding pregnant healthcare personnel. Immunizations required to work in the facility,[35] the responsibility for providing them, and work restrictions for unvaccinated employees should be outlined. Other vaccines that are recommended and offered by the facility but may not be required by law (e.g., influenza) should be listed in the guidelines. The guidelines should cover common restrictions regarding shingles, burns, fever, skin infections, and herpetic whitlow or other herpetic lesions. An algorithm outlining the severity of occupational exposures should be included. Guidelines should address common incidents, such as spitting and biting, and identify nonexposures that include body fluids such as saliva, urine, and feces that have no visible blood. Guidelines should include first-aid measures for bites that do not break the skin and required follow-up for bites that do break the skin, which increase the risk for infection. Guidelines apply to any employee, including contract employees, volunteers, interns, and students who work in the facility.

Conclusions

Behavioral health facilities are as diverse as the diseases they treat, which makes general assumptions concerning infection prevention at any like facility impossible. As alike as some facilities are, they differ in the populations served and the regulations of the jurisdiction in which they are located. Behavioral healthcare facilities are different not only from medical facilities but also from one another. The basic principles of infection prevention apply in behavioral healthcare, just as they do in acute care. The challenge to the IP in the behavioral healthcare setting is to adapt scientific principles to control the transmission of infection in a setting that may be less monitored and clinical, and with a population that is often less compliant than those in acute care. Education and networking with other professionals are essential elements to use in providing the facility with a sound infection prevention program.

International Perspective

The WHO Mental Health Gap Action Programme (mhGAP)[1] reported that a large disparity exists in mental health treatment between developed and less-developed countries. In a multicountry survey, mhGAP found that up to 85 percent of mentally ill persons had not received treatment in the previous 12 months. Almost a third of countries lack a mental health budget, and in those that do have a budget, the allocation of funds to research and treatment is minimal. Many mentally ill persons are not clients at all but are provided and cared for entirely by their families. WHO and its member states have committed to this area of public health to reduce the burden of mental illness globally, and are implementing strategies to close the gap between need and resources.

The guidelines suggested in this chapter outline basic infection prevention principles to support the efforts of IPs in countries with limited, but existing, resources for the treatment of mental health and in industrialized countries with relatively high resources.

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Cardiac Catheterization and Electrophysiology

Author(s): Kathleen Kohut, RN, MS, CIC, CNOR
Director of Infection Prevention

Cone Health
Greensboro, NC

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Abstract

Diagnostic and therapeutic cardiac catheterization procedures bypass natural host defenses and thereby pose a risk of infection. Early-onset infections resulting from these procedures can be related to bacterial entry into the host via the bloodstream. Therefore, sterile technique for vascular access is very important for all vascular access procedures. Especially worrisome are the late-onset infections that can occur with implantable devices (e.g., pacemakers, stents). Patient preparation and sterile technique are key strategies to reduce the risk of infection associated with these devices.

Key Concepts

- Cardiac catheterization procedures introduce the risk of infection.
- Early-onset infections are related to organism entry via the bloodstream during vascular access or intraoperative wound contamination.
- Late-onset infections are often associated with implantable devices.
- Patient preparation and sterile technique reduce the risk of infection.
- Use of Standard Precautions and compliance with sharps safety mandates minimize staff bloodborne pathogen exposure.
- Causative organisms of infection are usually normal skin flora and skin pathogens.

Background

The 20th century witnessed extraordinary advances in the diagnosis of heart disease, corrective surgeries, and other forms of treatment for heart problems. In 1929, German physician Werner

Forssmann passed a tube (catheter) from an arm vein into his own heart to prove that this technique could be used to administer drugs to the heart muscle. Although he was fired for this daring act, research on cardiac catheterization continued, and the technique came into common usage during the 1940s. In 1956, Forssmann was given a Nobel Prize in Medicine for his courageous and innovative work.[1]

It has long been recognized that the heart responds to an internal electrical stimulatory mechanism. The understanding of the electrophysiology of the heart and the great technological strides made in managing electrical currents made the treatment of this aspect of cardiac disease attainable. During the 1950s, active research and development led to new cardiac procedures and the development of cardiac devices to diagnose and treat arrhythmias and other cardiovascular diseases.

As experience with cardiac pacing via external transdermal myocardial electrodes progressed, it became apparent that electrode-associated infections would limit long-term external pacing. To avoid this complication, a totally implantable battery-powered pacemaker with a radiofrequency stimulator was developed and introduced clinically in 1959. Further advances resulted in the addition of a long-lasting lithium battery and the ability to externally program pacing parameters.

In the 1960s, more mechanical circulatory support devices were developed and used therapeutically in cardiac-compromised patients. In 1977, the first angioplasty was performed. A young Swiss physician, Andreas Gruentzig, inserted a balloon catheter (that he had developed in his own kitchen) into a patient's coronary artery, inflated the tiny balloon, and successfully opened a blockage and restored blood flow to the patient's heart. Today, more than two million angioplasties are performed worldwide each year. Technological advances in the field of cardiac catheterization and cardiac electrophysiology have made it possible for people with cardiac disease to obtain treatment that allows them to live active, healthy lives.[2]

Diagnostic and therapeutic cardiac catheterization procedures bypass natural host defenses, thus introducing the risk of infection. Early-onset infections following these procedures may be related to bacterial entry into the host via the bloodstream. Late-onset infections are associated with implantable devices (e.g., pacemakers, stents). Preparation of the patient and sterile technique are key infection prevention strategies in the cardiac catheterization laboratory (cath lab).

Basic Principles

CARDIAC CATHETERIZATION

Procedures performed in the cath lab provide important data to diagnose and treat heart disease with minimally invasive modalities. During the procedure, a physician inserts a catheter into the patient's blood vessel. Percutaneous vascular access is obtained most commonly via the femoral, brachial, or radial arteries and veins depending on the patient and the procedure. Procedures fall into one of two categories: diagnostic or therapeutic.

Diagnostic cardiac catheterization procedures are utilized to:

- Identify narrowed or clogged arteries
- Evaluate the heart's four valves
- Evaluate myocardial structure and function

- Assess for any congenital heart defects.[3]

Some of these procedures include:

- Coronary angiography, injecting a special dye (contrast medium) through the catheter and into the coronary arteries for fluoroscopic visualization of the coronary arteries (coronary angiogram)
- Hemodynamic testing to provide information regarding ventricular performance, cardiac output, vascular resistance, and shunt magnitude
- Vasodilator stress testing
- Intracardiac ultrasound and Doppler imaging are valuable adjunctive technologies utilized to diagnose and provide visualization during therapeutic procedures.

THERAPEUTIC

Therapeutic cardiac catheterization procedures are utilized to treat and improve heart function with interventions such as:

- Percutaneous coronary interventions (PCI), formerly known as percutaneous transluminal coronary angioplasty
- Transseptal catheterization utilized for mitral valvuloplasty, atrial fibrillation ablation, patent foramen ovale repair, atrial septal defects
- Left atrial catheterization for treatment of pulmonary stenosis
- Myocardial biopsies are performed for restrictive heart disease and heart transplant recipients.

Left ventricular punctures are utilized for percutaneous aortic valvuloplasty.[4]

PCI is the most common of these procedures and is performed to open up blocked coronary arteries. During PCI, a deflated balloon is threaded through the patient's coronary artery to the site of a blockage. The balloon is then inflated, crushing the plaque and restoring the normal flow of blood through the artery. Frequently, a stent is deployed after angioplasty to maintain patency of the blood vessel. The intraluminal coronary artery stent is a small, expandable, stainless steel mesh tube that is placed within a coronary artery to keep the vessel open. Drug-eluting stents are impregnated with drug-eluting material that suppresses endothelial growth to prevent restenosis (return of blockage due to immune or inflammatory injury) of the vessel.[4]

Electrophysiology procedures are done in special rooms called electrophysiology labs that have specialized equipment to diagnose and treat conductivity problems within the heart. The procedures most commonly performed in an electrophysiology lab include electrophysiology studies, radiofrequency and cryoablation to treat atrial fibrillation arrhythmias, and insertion of temporary and permanent pacemakers and implantable cardioverter defibrillators (ICDs).

Cardiovascular implantable electronic devices (CIEDs) such as pacemakers and ICDs are implanted to help correct cardiac arrhythmias. These battery-powered devices send electrical pulses into the heart tissue through permanently implanted electrodes that cause it to beat at a more therapeutic rate. The pacemaker can be programmed to start each heart contraction at the appropriate interval to provide an improvement in the heart's rate and rhythm. Dual-chamber pacemakers have become more common than single-chamber technology. An implantable ICD monitors the heart rate and provides low electrical impulses to correct arrhythmias or an electrical shock to prevent sudden cardiac death.[5]

The first transcatheter aortic valve replacement (TAVR) was performed in 2002.[6] TAVR is utilized as an alternative to surgical aortic valve replacements for patients with severe aortic stenosis. These patients are primarily elderly with multiple comorbidities that make them too high risk to undergo a surgical intervention. A mesh valve is inserted either percutaneously or via a transseptal approach into the existing aortic valve to improve function.

PEDIATRIC CARDIAC CATHETERIZATION

All specialized pediatric hospitals in the United States have cath lab facilities. The diagnostic procedures are used to identify structural heart abnormalities. More than 75 percent of all pediatric cardiac caths are diagnostic and therapeutic, treating many congenital abnormalities. Access may be the same as adults, but a carotid artery cutdown may also be used in children for certain procedures, and the umbilical vein is commonly used in newborns.[4]

VASCULAR PROCEDURES

In addition to coronary artery disease, these same types of minimally invasive percutaneous procedures are utilized to diagnose and treat blockages in larger vessels, such as the aorta, where endovascular aortic aneurysm procedures can now treat abdominal aortic aneurysms that meet specific patient criteria. Femoral and popliteal arteries that are compromised due to peripheral vascular disease and organ vessel blockages such as renal artery stenosis also may benefit from percutaneous catheterizations. The same principles are applied but the catheters and techniques vary depending on the patient and vessels to be treated.

Other advanced technologies performed in the cath lab include insertion of intra-aortic balloon pumps, extracorporeal membrane oxygenation, and intravascular ultrasound imaging.

HYBRID CATH LABS

Hybrid cath lab/operating rooms (ORs) are now being designed and constructed to maximize efficiency and provide state-of-the-art technologies to all physicians that perform these procedures. They may be located in the cath lab, surgical suite, or radiology. The providers may be interventional radiologists, cardiologists, or vascular surgeons. The radiographic technology supports optimal visualization to assist all providers with these complex and specialized procedures while providing a surgical environment if the need arises. Personnel from both the OR and cath lab may staff this area depending on the procedure.

CATHETER TYPES

Catheters are extremely diverse in shape, design, and feature depending on their function. Most catheters have at least one lumen. Multielectrode catheters, such as those used in electrophysiology studies, are generally solid catheters and do not have a lumen. The length of the catheters and guidewires, as well as the memory of the materials, may pose a risk of infection during use. They must be handled with great care to avoid hitting the operator(s) and/or the nearby equipment and thereby contaminating the catheter during use.

Some of the specific types of catheters used include:

- Central venous catheters
- Balloon flotation catheters (e.g., Swan Ganz)
- Right-side heart catheters

- Transseptal catheters
- Ventricular angiographic catheters
- Coronary angiographic catheters
- Multielectrode catheters, fixed curve or deflectable

VASCULAR ACCESS—INTRODUCING THE CATHETER

Catheters are introduced into arteries and veins using percutaneous approaches that involve needles and guidewires (direct surgical cutdowns are rarely performed and are considered a high risk for infection). The Seldinger technique (catheter exchange over a guidewire) is most often used for percutaneous insertion.

The femoral and brachial sites are most commonly used for entering the arterial circulation and for left-sided heart catheterization. The femoral and brachial sites also provide venous access and allow for the use of a single site if both arterial and venous accesses are required at the same time. Other sites for venous access include the subclavian vein and the internal or external jugular vein. The use of the radial artery for access has been increasing, as fewer complications have been noted with this site as compared to the femoral approach. This is because the radial artery approach allows for earlier ambulation because patients are not required to be prone during postprocedure hemostasis; it also provides better access in obese patients. The left side of the heart can be accessed using a direct ventricular puncture or a transseptal puncture.[4]

VASCULAR HEMOSTASIS POSTPROCEDURE

After completion of the procedure, the catheter and/or sheaths are usually removed. However, sheaths may remain in place if the site is to be used later, but this poses an increased risk for infection. Hemostasis is achieved through manual compression, mechanical compression, vascular closure devices, or percutaneous vascular sutures, clips, or collagen plugs. Vascular plugs are noncompression closure devices that were developed to circumvent the need for manual/mechanical compression to minimize bleeding complications. They include collagen-based sealing devices and suture- or clip-based closing devices. There have been reports in the literature of infections associated with closure devices. However, recent large studies have noted no increased risk for complications with their use.[7]

If femoral access was used and a vascular closure device was not utilized, the patient's activated clotting time is measured and must be near normal prior to removal of the sheath, at which time compression is applied. Patients must remain on bed rest, and the length of time for compression is dependent on the size of the sheath used and the patient's clotting ability. Hematoma formation and pseudoaneurysm are complications that may arise and lead to infection if hemostasis is not managed appropriately.[4]

Cath Lab Environment

The traditional cath lab operates in the hospital setting, where both inpatient and outpatient procedures are performed with an in-house cardiovascular surgery program to assist with complications that may arise and require immediate surgical intervention. Some cath labs are now located in hospitals and outpatient settings with no cardiac surgical program support. Implant procedures may be performed in

cardiac catheterization laboratories or in the operating suite. The same standards of care apply regardless of the setting, including the environment, patient care, and sterile technique.[8]

STAFFING

Cath lab personnel include the cardiologist, a scrub person, a circulator, and a control room monitor. The nonmedical staff generally include a licensed radiologic technologist who cares for the complex equipment, registered nurse that provide sedation and direct patient care, and technicians that may scrub, monitor, document, and run lab tests. These roles and staffing patterns may vary according to each facility, the acuity of the patient, and state law.[9]

CATH LAB SUITE

Many sophisticated radiologic, electronic, and computer-based systems are used in the cath lab. Standard cath lab suites include the procedure room and a control room with a large glass partition that allows for viewing of the procedure and is located directly outside the procedure room. Personnel in the control room, where the patient is monitored during the procedure and where all of the documentation takes place, are an important part of the team. In older cath labs, there may or may not be a door between these two areas. Newer construction includes a doorway to enable closing of the procedural area to optimize airflow, reduce traffic, and prevent contamination during the procedure. The scrub sink may be located within the procedure room itself or may be placed in the control room or other area adjacent to the procedure room. Equipment and storage supply rooms, a patient holding area where preprocedural preparation takes place, recovery room, pharmacy space, blood-gas analysis area, image viewing area, computer processing area, and dirty and clean utility rooms support the activities of the department.

The American Institute of Architects (AIA) specifies new construction requirements for cardiac cath labs.[10] The specifications include standards for square footage, air exchanges, temperature, and humidity (see Table 50-1). Scrub sinks must operate with hands-free controls and be adjacent to the procedure rooms. Traffic patterns should be established to reduce the risk of infection, such as locating staff dressing room access directly to the cardiac catheterization suite. In most instances, the clean utility room contains a work counter and a dedicated hand-washing sink. The dirty utility room contains a dedicated hand-washing sink and an equipment-cleaning sink. The materials used must be nonporous and cleanable to reduce the bioburden in the rooms. Materials such as wooden shutter doors, carpeting, wooden shelving, etc. are not suitable for this environment. Care should be taken not to store equipment in front of the return vents in the room, as this will impede airflow. Likewise, when doors are left open the air cannot be filtered properly and the positive air pressure in the room may be compromised.

Air exchanges and airflow should be documented at least annually and after any disruptions or modifications to existing systems. Temperature and humidity should be monitored daily in these rooms to ensure the integrity of the sterile equipment, supplies, and room environment to prevent bacterial growth and decrease the risk of infection.[11] When the temperature and/or humidity are out of range, facilities personnel should recheck the results to ensure accuracy and make corrections as necessary. If this occurs over a prolonged period of time, re-sterilization of instrumentation/reprocessed supplies and terminal cleaning of the room may be required. This decision should be made in consultation with sterile processing, infection prevention, and cath lab leadership.

Table 50-1 Cardiac Cath Lab Procedure Room Specifications

Specifications	Therapeutic Procedure Rooms
Square footage	Minimum 400 sq ft (37.16 sq meters)
Air exchanges	Minimum 15 per hour (3 must be fresh air)
Airflow	Positive to adjacent areas
Temperature	70ºF –75ºF (21ºC–24ºC) maximum
Humidity	60% maximum

Storage space is typically at a premium and equipment is frequently stored in the rooms when not in use. This equipment should be covered to prevent dust and cross-contamination. Lead aprons and collars should not be stored in the rooms to decrease traffic flow and cross contamination. Catheters and other sterile supplies that are stored in the rooms should be contained in closets or lockers to protect them from contamination. Sterile supplies and equipment should never be stored near sinks because of the potential of moisture and aerosolized waterborne organism contamination.

Epidemiology of Infection

RISK OF INFECTION

The risk for infection postprocedure is multifaceted depending on the patient factors and procedural characteristics. Although various studies report patient factors that were unique to their study populations, overall literature agrees that comorbidities such as cardiac disease, renal disease, and diabetes, as well as immunosuppression therapy, malignancy, steroid therapy, and advanced age are the most significant factors that predispose a patient towards infection. A single-center study of primary implantation of cardiac devices between 1996 and 2007 noted that two of the factors that were independently associated with infection were diabetes and underlying heart disease.[12] In a case control study by Sohail et al. multivariate analysis revealed long-term corticosteroid use as an independent variable for infection.[13] In another study of 28,250 procedures performed in a 60-month period, multivariate logistic regression demonstrated that renal impairment was the most significant predictor of postcatheterization bloodstream infection (BSI).[14]

Procedural risks are dependent on the type of procedure performed and the presence of an implanted device. Procedural factors that may influence the outcome may include the number of procedures, duration of the procedure, low volume/operator experience, and development of hematoma. Analysis of REPLACE registry data, a prospective, multicenter study from 72 United States sites over a 6-month period, demonstrated a higher risk for infection with increased comorbidities, hematoma formation postprocedure, and having the procedure performed in a facility with low implantation volume.[15] Different procedures also pose different risks and yield different outcomes. Diagnostic catheterization procedures are typically the lowest risk for infections, but insertion site infections, pseudoaneursyms, bacteremia, and/or systemic infection can occur as postprocedure complications. Therapeutic catheterizations that involve implantable devices pose the highest risk. With these procedures, surgical site infections (pocket infections), infectious endocarditis, and bacteremias are commonly reported in the literature with associated morbidity and mortality. Risk factors unique to these procedures are previously implanted device, fewer than two pacing leads, early lead dislocation, skin contamination, and failure to administer antibiotic prophylaxis.

Although underlying conditions (including diabetes, malignancy, skin disorders, malnutrition, anticoagulant use, steroids, and immunosuppressive drugs) were predisposing factors, postprocedure hematomas, seromas, and recurrent surgical manipulation at the pacemaker site also increased the risk of infection. It is also well documented that hematogenous seeding of implantable device sites from remote infections (catheter-associated sepsis, sternal wound infections, etc.) or from unrelated transient bacteremia can result in site infections.

Pacemaker infections may present as local inflammation and abscess formation in the pulse generator pocket, fever with positive blood cultures with or without a focus of infection elsewhere, or erosion of part of the pacing system through the skin. Pacemaker lead (wire) infections typically occur within 1 month of insertion and are a result of contiguous spread of bacteria from an infected pacemaker site or from contamination after the wire has eroded through the skin. Bacteremia is infrequently seen when infection occurs in the pacemaker generator pocket, and pocket infections are the most commonly reported infection type related to pacemaker procedures.[16]

INFECTION RATES

Infectious complications from pacemakers are reported in the literature as between 1 and 7 percent for all devices and were validated in a study by Tischer et al. in a 40-year historical perspective of a single center.[17,18] A meta-analysis of ICD literature reports an infection rate of 1.4 percent for these devices.[19] A review of coding data at a 750-bed tertiary referral hospital from January 2005 through December 2009 revealed a cardiac catheterization BSI rate of 2.3 cardiac catheterization-associated BSI per 1,000 procedures, which is similar to other studies noted in the literature.[14] Voight et al. reported an increase in the incidence of infections for CIED procedures in the 1996 to 2006 study period and cited comorbidities and more complex procedures as potential causes.[17] The National Health and Safety Network (NHSN) reports a pooled mean of pacemaker infection rates of 0.44 percent from data reported between 2006 and 2008. However, this represents just 17 hospitals and 3,403 procedures, which is far too small to reflect the number of procedures performed during this same time period.[20]

Although the data reported are informative and instructional, there is a lack of continuity and standardization that is required to be able to apply sound epidemiology to these infections. There is no consensus in the literature regarding infection definitions, criteria, and surveillance time frames that can be uniformly applied to the infectious complications reported, and therefore no useful benchmarks exist at this time. Acute infections that can be attributed to the procedure are defined by NHSN as occurring within 30 days of the procedure or within 90 days if a device has been implanted (a change in definition that took place in January 2013).[21] However, the literature frequently cites infection rates that also include chronic infections that occurred after 1 year. Likewise, bacteremia rates postcatheterization do not have a defined time frame, which may be erroneously attributing infection to the procedure rather than to a transient bacteremia related to a remote infection. Therefore, benchmark comparisons of infection rates cannot be clearly understood at this time. Dicks et al. have proposed a definition for BSI following cardiac catheterization procedures and may ultimately provide a basic framework to apply epidemiologic principles to assess risk, attribute cause, and improve prevention efforts.[14]

MICROBIOLOGY OF INFECTIOUS COMPLICATIONS

Normal skin flora can be introduced into the wound bed or may contaminate the catheter hub, which then increases the risk for infection locally or systemically. In one study of BSI surveillance conducted during a 60-month period postcardiac catheterization, an overall incidence rate of 2.3 BSIs per 1,000

procedures was noted. The most commonly reported organism was *Staphylococcus aureus* (of which 33 percent were methicillin-resistant *S. aureus*) followed by coagulase-negative *staphylococci*(CNS), *Escherichia coli*, and polymicrobial sources, respectively.[14]

*Staphylococcal*species account for 60 to 80 percent of reported cases of implantable infections and are frequently the causative organism in early infections (defined as within 30 days of the procedure). CNS species have been reported in the literature as a primary cause of late-onset infections when implantable devices are present. This is in large part due to the slow-growing nature of CNS and its ability to adhere to foreign objects. Gram-negative bacteria and fungi such as *Candida*spp. cause a minority of infections.[16]

Normal skin flora and skin pathogens (including methicillin-sensitive *S. aureus*and methicillin-resistant *S. aureus*) may come from endogenous sources such as the patient's own hair and skin cells. Strict attention to the patient's bioburden with particular focus on the axilla and groin during the skin prepping process is important to mitigate this risk. Exogenous sources such as healthcare provider shedding and environmental contamination require proper attire, strict sterile technique, and proper cleaning procedures to reduce the bioburden in the environment and potential sources for wound contamination. Analysis of the causative organisms is important to direct action plans in order to prevent future infections.

In the past it was theorized that oral pathogenic flora accounted for an increased risk for infection in patients with implanted devices. Antibiotic prophylaxis was highly recommended for these patients when routine invasive procedures such as dental, gastrointestinal, or genitourinary procedures were performed. However, this is no longer the case. It is now believed that when bacteremia caused by oral microbial flora does occur, it is more likely the result of common daily activities such as chewing food and brushing teeth. Therefore, prophylactic antibiotics when undergoing procedures are no longer recommended for patients with cardiac implantable devices.[16]

TREATMENT CONSIDERATIONS

Treatment for infection is dependent on multiple factors, including comorbidities, presence of an implant, causative organism, and type of infection identified. Baddour et al. published comprehensive recommendations for management of these infections, including antibiotic treatment and decisions for explantation of the devices. For patients without implanted devices, appropriate antibiotic therapy is sufficient. Patients with implanted devices are at greater risk, and many variables must be considered. Overall consensus is for complete explantation of the device, including leads, when definitive CIED infection is diagnosed.[16]Pichlmaier et al. demonstrated infection all along the leads in a 3-year study of 71 patients with explanted devices for CIED diagnosis. This confirmed the need for complete explantation.[22]A study of 189 cases of pacemaker and *Clostridium difficile* infections by Sohail et al. demonstrated a 96 percent successful treatment with antibiotics and complete removal of the implanted device.[23]Explantation does come with risk, as older leads are more likely to adhere to the vessels and coronary sinus ostium as compared to newer leads (defined as less than 2 years). Therefore, explantation increases the risk for blood loss, hematoma formation, tamponade, and death.[24]

Lead extraction can be performed by surgical or percutaneous intervention. Laser-powered sheath technology may be required in patients with older leads. Overall success rates are reported between 98 and 100 percent. The timing of re-implantation is not well understood. Re-implantation on the same day

as explantation may be possible if only localized superficial pocket infections are diagnosed. This may be an important option for patients that are pacemaker dependent. Same-day contralateral implantation may be performed after the initial removal of the previous implant, thorough pocket debridement, and utilization of the opposite side. Mountantonakis et al. reported no infections of the new implants after a minimum of 1-year follow-up using this same-day technique.[25]

TAVR infections pose significant management challenges and are not well studied. Surgical intervention, which is common in surgically implanted aortic valve replacement infections, is rarely an option for TAVR patients because of the frailty of this population and the significant comorbidities that disqualify them for surgical intervention in the first place. Mortality rates as high as 33 percent have been reported.[26]

Infection Prevention in the Cath Lab Setting

HAND HYGIENE

Hand hygiene is one of the most important infection prevention strategies, as the risk of horizontal transmission of organisms during the procedure is high. However, hand hygiene in procedural areas should be performed more frequently than when the patient is in his or her room on the nursing unit. Hand hygiene opportunities are based on contact the providers have with the patient. These include the times prior to donning gloves to provide patient care, after removing gloves when care has been completed, before and after transferring the patient onto the procedure table, before and after positioning the patient, and before and after moving the patient onto the stretcher for transport to the recovery area.

Please refer to **27. Hand Hygiene** for further information.

STANDARD PRECAUTIONS

All staff that perform or assist with procedures in the cath lab must comply with Standard Precautions to manage the risk of exposure to blood and body fluids. Personal protective equipment (PPE) must be readily available and staff trained in its proper use. Workflow must be continually assessed and redesigned when applicable to minimize aerosolization and splattering of blood and body fluids. Hepatitis B vaccination is strongly recommended for all healthcare providers because of the high risk of exposure to blood and body fluids.[27]

See **29. Isolation Precautions (Transmission-based Precautions)** and **103. Immunization of Healthcare Personnel** for further information.

PERSONAL PROTECTIVE EQUIPMENT

PPE is used for the prevention of exposure to blood and body fluids for staff, as well as a means of protection from infection for patients. Gloves used during procedures should be sterile; they are donned in a manner to prevent contamination of the outer glove surface. Hand hygiene is required before and after donning sterile gloves.

Gowns must be worn during procedures to prevent exposure and to contain healthcare provider shedding onto the sterile field. Gowns should be nonporous and worn over a scrub suit or clean hospital uniform (not street clothes). Shoe covers may be worn to protect shoes from being contaminated with blood and to prevent tracking blood on the floor from soiled footwear. Scrubs and shoe covers must be

changed when visibly soiled or contaminated by blood and body fluids. Masks, protective eye gear, and protective caps are worn to prevent blood and body fluid exposure and to contain harmful organisms that may be shed by the healthcare provider into the environment.

PREPROCEDURE

Patients who are diagnosed with an infection prior to elective procedures must be adequately treated prior to the procedure being performed.[28] Patients with diabetes should be well managed prior to the procedure whenever possible. Preoperative bathing programs are implemented to reduce the bioburden on the patient's skin to prevent endogenous sources of wound contamination. Antibiotic prophylaxis is not routinely recommended for diagnostic procedures performed in the cath lab.

Antibiotic prophylaxis is recommended whenever a device is implanted.[29] A large prospective, randomized, double-blinded, placebo-controlled trial of 1,000 consecutive patients undergoing pacemaker and ICD procedures was terminated early because of the significant favorable difference in outcomes in the patients receiving prophylaxis as compared to the placebo group.[30] When antibiotic prophylaxis is appropriate, the antibiotic chosen should be effective against common skin organisms, given in the appropriate timeframe (30 to 60 minutes prior to procedure), and discontinued within 24 hours. Dosing is now considered weight based, with larger patients receiving higher doses to ensure proper tissue levels intraoperatively. Redosing is also recommended for long procedures and is dependent on the half-life of the antibiotic. For example, cephalosporins should be repeated every 4 hours from the initial preoperative dose.

Hair should be removed from the access site(s) only if absolutely necessary. If hair is to be removed, use clippers or a depilatory. Hair should be removed immediately before the procedure but not in the procedure room itself to reduce the bioburden in the presence of the sterile setup. Hair should be clipped in the holding area just prior to transfer to the procedure room.[31]

All healthcare personnel who work at the sterile field on cases with a surgical incision and when an implant will be utilized must perform a surgical hand scrub prior to every procedure. Mechanical surgical scrubs with an antimicrobial soap and alcohol-based hand rubs with persistent activity are recommended. The persistence of an active antimicrobial is required, as cases take time to complete and microbial counts will increase on the provider's hands and forearms over time. The antimicrobial properties will continue to reduce this bioburden and potential source of infection throughout the length of the procedure.[32]

PROCEDURE

The CDC 2011 *Guideline for the Prevention of Intravascular Catheter-related Infections* recommends the use of maximum sterile barrier precautions for the insertion of central venous catheters, including cap, mask, sterile gown, sterile gloves, and sterile full-body drape to protect the patient from the risk of infection, and this same recommendation should also apply in the cath lab setting.[33] Kern noted that current practice around the world is variable and a cause for much controversy.[34] He states that, at a minimum, hat, gown, gloves, and mask should be worn to comply with the Occupational Safety and Health Administration (OSHA) ACT 29 CFR 1910.1030 regarding protecting the worker from exposure to bloodborne pathogens.[27] The general consensus in the literature is that although infections are rare, they can be devastating to patients. Therefore, the highest standards should apply when performing the

highest-risk procedures, such as implantation of devices. If electrophysiology labs are the only place that these procedures are performed, it is easy to have standardization in this environment. However, many cath labs perform different procedures in any available room depending on throughput and emergencies. Consideration regarding cath lab standards for attire, traffic patterns, and terminal cleaning must be established to protect the patients from the risk of infection.

Borer et al. describe an increase in infections associated with cardiac devices, noting additional evidence in support of basic infection prevention practices in a study. Interventions to reduce infections included basic infection prevention practices such as surgical skin preparation of the patient; surgical hand antisepsis; using hats, masks, gowns, and gloves; and improving cleaning procedures. These interventions resulted in a statistically significant reduction in infections in this population.[35]

Skin antisepsis of the access site using a broad-spectrum antimicrobial agent is done immediately before the procedure. The CDC recommends a greater-than 0.5 percent chlorhexidine gluconate (CHG) with 70 percent alcohol or an iodophor with 70 percent alcohol preparation.[33] The use of iodophor-based preps without alcohol have been shown to be less efficacious than preps that contain an antimicrobial and alcohol combination.[36]

Sensitivities to CHG or iodophor must be taken into consideration when choosing the prepping product. It is important to follow the manufacturer's instructions for preparation of the site with the chosen skin antisepsis product (including dry times) because the different products and preparations differ substantially in the method of preparing the site. Drapes are selected for maximum sterile barrier coverage of the area surrounding the access site. The drape must be nonporous and be able to completely cover the patient and hardware attached to the table that could come in contact with the catheter or wires.

Traffic should be kept to a minimum once the sterile field has been established. The door should be closed during the case (if one exists) except for necessary traffic. Communication to the team in the lab should be conducted from the control room whenever possible to avoid entering the suite while the procedure is taking place.

Standards of practice to minimize the potential for contamination of equipment include:

- Maintaining the principles of sterile technique in the presence of a sterile field
- Covering equipment near the catheter entry site to protect against possible blood contamination
- Using fine and monofilamentous suture material
- Use of disposable (single-use) catheters if possible
- Proper sterilization of reusable equipment
- Utilizing injection safety practices

Safety injection practices can be a challenge in the cath lab environment because some medications such as contrast, heparinized saline, and nitroglycerin do not always come pre-prepared in quantities convenient for use in this setting and provide challenges to cost containment. Some cath labs choose to use these multidose vials and document the date and time when they are opened as well as the expiration date. They are thrown away after 24 hours. Sterile needles and syringes must be used each time the bottle is entered, and careful cleaning of the hub prior to entry is required. Best practice is to use a new bottle for each patient. Fluid management injection systems utilize contrast and heparinized saline for multiple patients. These devices are used to inject contrast medium and then flush the line

afterwards with the heparinized saline during the procedure. The tubing setup contains a patient-dedicated removable line with a one-way valve to prevent backflow and potential contamination.

Case setup should occur immediately before the start of the procedure to ensure sterility. Setting up procedure tables ahead of time is common practice for diagnostic procedures but should be discouraged. Setting up and covering sterile tables for implantable procedures should not occur due to the high risk of the procedure as the table can be contaminated while stored for use or during the removal of the drapes.

Once sterile supplies have been opened, strict adherence to sterile technique is required for implantable device procedures.[4] Dressings should be applied in a sterile fashion prior to drape removal. An occlusive dressing should be applied and left in place a minimum of 24 to 48 hours to promote wound healing. If a pressure dressing is required, it can be placed on top of the occlusive dressing.[28]

POSTPROCEDURE

Patient management to prevent infections after the procedure involves nursing standards of practice related to sterile technique for wound care, site visualization and care for the prevention of hematoma formation, monitoring of sheaths left in place, and glucose management. Patients should receive education and discharge instructions related to their postprocedure care, as well as information related to any closure devices used during the procedure.

CLEANING

Cleaning between cases should be performed after each case and all trash should be removed. The immediate environment is cleaned, including the procedural table, all furniture utilized during the case, and any area visibly soiled. The floor does not need to be wet mopped unless visibly soiled. Lead aprons and collars should be wiped down after each healthcare provider is done for the day or if visibly soiled.

Waste disposal is performed by discarding fluids through the manifold via the extra port that contains a one-way valve to a disposal bag. Puncture-proof sharps containers for needles and blades should be used and blood-contaminated disposables should be discarded in appropriately labeled waste containers according to OSHA guidelines.

Terminal cleaning should be performed at the end of each day to reduce the bioburden in the room. Terminal cleaning includes wiping down all furniture and equipment in the room, with special attention to all of the cords, tubing, and monitors in high-dust areas located throughout the lab. The floor should be wet vacuumed or cleaned with a single mop head per room with an Environmental Protection Agency–registered disinfectant per CDC guidelines. The air vents should be inspected and cleaned monthly and as needed.[37]

Environmental service personnel responsible for these activities should be specially trained by the cath lab staff on how to safely clean the technology and surrounding areas according to manufacturer's recommendations.

THIRD-PARTY REPROCESSING

The U.S. Food and Drug Administration (FDA) began regulating hospitals engaged in reprocessing single-use devices (SUD) in August 2000, in the same way it regulates device manufacturers. Cath labs may consider reprocessing at the facility or by using third-party reprocessors; the decision is based on

potential cost savings. However, the safety and costs associated with this process must also be considered. The FDA has a proposed list of "Frequently Reprocessed SUDs" that may be used in cardiac catheterization and electrophysiology procedures.[38]

TRANSMISSIBLE PRION DISEASES AND REUSE OF ELECTROPHYSIOLOGICAL CATHETERS

Reuse of electrophysiology catheters is an important consideration for many electrophysiology laboratories. However, the North American Society of Pacing and Electrophysiology has recommended against reuse of an electrophysiology catheter after it has been used on a patient with Creutzfeldt-Jakob disease (CJD) or another spongiform encephalopathy caused by prions.[39]This recommendation focuses on the lack of effectiveness of current reprocessing in eliminating contamination by CJD and does not consider the infectivity (or lack thereof) of the tissue or fluid that contaminate electrophysiology catheters.[39]

For more information, see **32. Reprocessing Single-Use Devices** and **73. Creutzfeldt-Jakob Disease and Other Prion Diseases**.

Conclusions

Diagnostic and therapeutic cardiac catheterization procedures range from minimally invasive procedures to high-risk surgical procedures. Although infectious complications are considered rare, the risk of infection following these procedures is multifactorial and dependent on the patient's health, the procedure, and healthcare provider practices. Regardless of the cause, infections can be devastating to the patient and may result in death. As the complexity of the procedures increase with advancing technology, infection prevention standards must also increase. Basic infection prevention principles must be adhered to during all sterile procedures. The highest standards of care must always be practiced for high-risk procedures to prevent infection. Patient preparation, antibiotic prophylaxis, sterile technique, and environment of care practices must be evaluated and changes implemented as needed. Monitoring should occur to maintain these practices for every patient in every case.

Future Trends

As technology continues to advance, interventional procedures are sure to follow, and settings such as the cath lab will become multidimensional. The procedures will become more complex, as will the patients—who will be older and present with multiple comorbidities. It is likely that cath labs will become "interventional labs" similar to the hybrid labs being used today. These labs will enable all disciplines to access the most optimal environment with advanced imaging and technology to care for their patients while enabling acute care organizations to consolidate resources. Coronary, cerebral, and vascular vessels will be accessed to treat conditions previously regarded as untreatable.

In addition, the hybrid concept is likely to expand to accommodate the dual roles of minimally invasive surgical procedures performed simultaneously with percutaneous procedures. The hybrid coronary revascularization procedure involves minimally invasive off-pump coronary artery bypass grafting with simultaneous coronary stenting and is already being performed in some acute care centers.

Emerging technologies may include leadless pacing systems and biological pacemakers, tissue that when implanted will regulate the heart. Implantable devices will become more prevalent as the technology for procedures such as TAVR continues to grow. These types of procedures utilizing sophisticated implants will pose greater risk for infection than cath labs have experienced in the past. Journals are already reporting adverse outcomes related to TAVR procedures and Ian Gilchrist, in an editorial comment, describes the casual approach to infection prevention that cardiologists have demonstrated in the past.[40]

Cardiologists cite a lack of infection rates in the cath lab to defend these practices, and the argument is not without merit. Surveillance of this patient population has had minimal focused attention. Increased efforts to improve surveillance in the cath lab will be necessary to protect patients and prevent infections in the future.

Changes to surveillance will require a consensus on definitions for infection related to bacteremia, surgical site infections, and endocarditis. Dicks et al. have begun this work with bacteremias, and NHSN has established definitions for SSIs in the pacemaker population that should be expanded to further include all CIEDs and other implantable devices.[14]

Postdischarge surveillance is challenging for infection preventionists. As patient care delivered in diverse settings continues to grow, the ability to follow these patients will become increasingly difficult. The federal government's Meaningful Use program may one day enhance the infection preventionist's ability to access patient information postprocedure when all patient care sites have electronic medical records. The concept of "one patient, one chart" will improve the continuity of care and present great potential for data mining for quality improvement activities such as infection prevention.[41]

International Perspective

Research literature is published regularly related to infection rates and other complications from countries around the world that perform cath lab procedures. It is estimated that over 15 million percutaneous arterial catheterizations are performed each year worldwide.[7]However, health disparities exist between the wealthy and low-/middle-income countries.[42]For example, Pavri et al. report ICD implantation rates for many Asian and South American countries as one per million persons as compared with 434 new implants per one million persons in the United States.[43]Pavri demonstrated in a small cohort of 81 patients that implants with 3 or more years of implantable life can be safely reprocessed and reused without an increased incidence of complications. However, many obstacles to obtaining the devices for the study were encountered.

Currently, the FDA does not allow the reuse of these devices in the United States, citing a lack of evidence as to the safety of reprocessing even though re-implantation of these devices has been ongoing in other countries for many years.[44]However, there are no available data from these countries to understand the risk of infection related to these procedures. Therefore, standards must be established to determine the feasibility and safety of reprocessing these devices. In addition, the logistics of obtaining the devices for reprocessing, as well as the legal and ethical issues surrounding such a process, must be addressed. The infection prevention community must be active in this conversation to ensure the safety of patients around the world that require greater access to this technology that will enable them to lead longer and healthier lives.

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Correctional Facilities

Author(s): Alexander Tomich, DNP, RN, CIC
Director, Infection Prevention and Control

Rush University Medical Center
Chicago, IL

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Abstract

The correctional setting includes a wide range of penal institutions: jails, state and federal prisons, and juvenile detention centers. Each correctional system has its own internal culture that presents unique challenges to the infection preventionist. The demographics of the population in each system are often similar: inmates are disproportionately poor, male, medically underserved, and from minority groups. The 7 percent (approximately) female prison population has added issues of being victims of domestic violence and/or having a history of sexual abuse. Prison healthcare provides a window of opportunity for inmates to receive medical care and risk-reduction information that they might not otherwise obtain. Most inmates eventually do return to their communities, and those communities can directly benefit from these disease prevention and treatment efforts.

In this setting, the infection control program faces issues such as overcrowding, a population with increased risk of infection with bloodborne pathogens and other infectious diseases, frequent inmate movement, and an environment that is primarily restrictive. Inmates are a challenging population to work with and may exhibit characteristics such as extreme manipulativeness, dishonesty, and violence. They may be bored or exhibiting attention-seeking behavior and may not be receptive to medical interventions or education. Any medical care provided to inmates is an additional cost to the system and not aligned to the primary purpose of incarceration. When looking at trends in prison management, there are comparable issues seen throughout the healthcare setting involving medical staffing. Prisons are generally extremely short-staffed and because of chronic shortages of registered nurses, licensed vocational nurses may provide significant portions of the care.

Key Concepts

- Correctional settings have a concentration of medically underserved individuals with a greater prevalence of bloodborne pathogens, sexually transmitted diseases, and tuberculosis.

- In correctional settings, the first priority is always maintenance of security, which creates challenges when striving to implement infection prevention and control policies and procedures.
- Correctional facility employees have a high risk of communicable disease exposure because of overcrowding, old facilities, and a potentially violent, high-risk population.
- Correctional environments are generally not accepting of harm-reduction interventions such as provision of condoms, bleach, needles, and syringes.

Background

OVERVIEW OF THE INCARCERATED POPULATION

The United States has the highest incarceration rate in the world with an estimated 937 adult prisoners per 100,000 residents and 2,015 per 100,000 adults under supervision, parole, or probation.[1] At the end of 2011, nearly 2.3 million inmates were in correctional facilities in the United States, a decrease of 1.3 percent during the year. This represents a 3-year decline in both federal and state correctional populations.[1,2] Approximately one-third of inmates are in jails or short-term facilities, serving sentences as short as 1 day before returning to their communities.

To clarify some of the terminology used in this chapter, lockups are temporary holding facilities of a federal, state, or local law enforcement agency. Lockups include locked rooms, holding cells, or cell blocks under the control of a law enforcement officer. Jails are administered by county or city governmental agencies, often a sheriff's department. A jail may house persons convicted for misdemeanors or picked up for parole violations, as well as those awaiting hearings, trial, or transfer to prison. Sentences are usually less than 1 year. State prisons house people convicted of felonies under state law. State prison sentences are 1 year or longer. Federal prisons house people convicted of violating federal laws. These prison sentences are at least 1 year. Levels of security will range from honor camps that inmates could walk away from if they so choose to maximum security prison; the lower the level of security required or degree of prisoner movement, the easier it is to implement screening, treatment, and educational programs in these facilities. Prisoners are often referred to as inmates or detainees. When inmates are released on parole, they are assigned a parole officer whose duty is to track the parolee's activities and ensure referrals for social assistance for a designated period of time until the individual is off parole.

The Bureau of Justice Statistics reported in 2004 that approximately 40 percent of inmates reported having some physical or mental health problem.[3] Inmates were determined to have a current medical problem if they reported having at least one of 14 specific problems: arthritis, asthma, cancer, diabetes, heart problems, hypertension, kidney problems, liver problems, paralysis, problems due to a stroke, hepatitis, human immunodeficiency virus (HIV), a sexually transmitted disease (STD), or tuberculosis. Among female prisoners, 4 percent of state and 3 percent of federal inmates said they were pregnant at the time of admission.[3] Females have often been abused and may have been given many more chances to stay out of prison before being incarcerated. They are also less likely to be incarcerated for violent crimes. Sexual abuse of juveniles was estimated to be 90 percent for females and 25 percent for males. Women inmates have higher rates than male inmates of drug use, HIV infection, and STDs. At the end of 2004, 1.9 percent of all female and 1.6 percent of all male state inmates were HIV positive.[3] Hepatitis infection was even more common—5.3 percent of state inmates and 4.2 percent of federal inmates were infected.[3] Infections with bloodborne pathogens are more frequently seen in inmates older than 45 years

of age. More than one-third (36 percent) of state inmates and nearly one-quarter (24 percent) of federal inmates also reported having learning, visual, and/or mental health impairments.

The HIV epidemic continues to affect injecting drug users, their sexual partners, and their children. National and state drug policies mandate minimum sentences for drug crimes. Thus, the number of inmates has surged in recent years in large part due to drug-related arrests and prosecutions. About 80 percent of inmates have substance abuse problems and significantly higher rates of communicable diseases compared with the general population. Correctional staff are at potential risk of occupationally acquired infections, including bloodborne and airborne pathogens such as Hepatitis B virus (HBV), Hepatitis C virus (HCV), and *Mycobacterium tuberculosis*.[4,5]

In 2009, more than five million inmates were placed under community supervision, which includes probation and parole. An estimated 95 percent of all state-held prisoners will be released from prison at some point, but recidivism (re-arrest) rates may be very high for those who have a history of violent crime. With the revolving door between prisons and communities, incarceration provides a window of opportunity and a challenge to diagnose, treat, and endeavor to provide continuity of care upon release. Effective interventions in this population require close collaboration between local and state health agencies and correctional healthcare services. This includes discharge planning with linkage to community agencies for follow-up, educational programs, policy and procedure development, surveillance and screening activities, and assistance with prophylaxis, treatment, and outbreaks of communicable disease.

Infection prevention and control programs in jails will be somewhat different from those in state and federal prisons as a result of higher turnover, sentencing mandates, and security issues such as the need to minimize gang activities and contacts. Interfacility transfers are common in all settings.

Basic Principles

ESSENTIAL ELEMENTS OF THE INFECTION PREVENTION PROGRAM IN THE CORRECTIONAL SETTING

Recognizing the importance of infection prevention and control in the correctional setting, the National Commission on Correctional Health Care (NCCHC) identified an effective program as an essential standard for correctional institutions seeking accreditation through NCCHC.[6]The American Public Health Association (APHA) Task Force on Correctional Health Care Standards stated, "each prison or jail must have an infection control program that effectively monitors the incidence of infectious and communicable diseases among prisoners and staff."[7]

The objective of the infection prevention program in the correctional setting is the promotion of a safe, healthy, and therapeutic environment that fosters health-maintaining and health-promoting behaviors in staff and inmates, prevents or minimizes occurrence and transmission of communicable disease, and ensures prompt and appropriate implementation of available prophylactic and therapeutic measures when necessary. To meet this objective, an infection prevention program should include the following essential elements:

- A designated person responsible for the infection prevention program: In a large correctional institution or system, this person should be a licensed independent provider specializing in infectious diseases or an infection preventionist (IP). In small facilities with only part-time medical presence, the

medical or nursing director or a public health nurse can be the responsible person who provides the necessary guidance to other staff. In large state settings, there may be a designated IP either on a regional or institutional level. The level of training and education for this position may vary and should be developed.

- Written policies and procedures for screening, surveillance, and control of infectious and communicable disease outbreaks in inmates and staff. This includes preventive and control measures specific to the disease and setting and appropriate treatment of the identified cases. Surveillance includes statistical record keeping, analyses of trends over time, and notification of reportable communicable diseases to the appropriate authorities in compliance with local and state requirements. Surveillance may be focused on infections that can become epidemic in this population (e.g., chickenpox, respiratory/influenza-like illness, foodborne illnesses), require reporting to the health authority, or create panic or anxiety in staff (e.g., meningitis or community-associated methicillin-resistant *Staphylococcus aureus*[CA-MRSA]). It is essential to remember that correctional staff members are not trained healthcare professionals and may overreact to what they perceive to be highly infectious disease conditions, such as positive tuberculin skin tests.
- Environmental control policies and procedures for maintenance of a clean, safe, and healthy environment. These policies should be in compliance with state and local regulations on medical and nonmedical waste disposal, water supply, sewerage, ventilation, pest control, food handling and preparation, and laundry and housekeeping practices, with appropriate education for staff and inmates who may be assigned these tasks.
- Written policies and procedures that ensure compliance with all appropriate Occupational Safety and Health Administration (OSHA) guidelines. Educational programs in infection prevention work practices should be provided to specific groups of workers (incarcerated or civilian) in the following areas: laundry, housekeeping, food service, and other areas as appropriate.
- Ongoing educational programs about relevant communicable diseases for incarcerated populations as well as nonmedical and medical staff who are appropriate to each audience. Educational programs also should provide basic instruction on good personal hygiene practices and principles of disease transmission and harm reduction.
- A multidisciplinary infection control committee chaired by the chief medical officer of that prison or group, or the responsible infection prevention and control program, make recommendations for improvement, and address outbreaks or other urgent infectious disease situations. This committee may be a quality management committee that incorporates the infection prevention and control program.
- Interaction with local or state departments of public health and other agencies and hospitals that may have responsibility or oversight of the correctional healthcare. NCCHC and the American Correctional Association have national accreditation programs designed for correctional healthcare services.[6,8,9] As such, they have defined minimum requirements for such facilities to attain accreditation.

Infection Prevention And Control In Correctional Facilities

SPECIFIC COMMUNICABLE DISEASES

Because of the nature and design of correctional facilities (overcrowding, frequent movement, and security issues) and characteristics of incarcerated populations, specific communicable diseases are more prevalent compared to civilian populations. Intake or admission to a correctional facility occurs in stages: (1) screening for communicable diseases that are actively contagious; (2) completion of a

medical assessment that includes sections on personal risk factors, family history, and surgeries/hospitalizations; and (3) a physical examination section that requires assessment of relevant vital signs, and those aspects of the examination appropriate for any chronic disease identified, including a mental health screening and a review of the inmate's past medical history as available. Females will be screened for pregnancy. The identification of preexisting conditions upon entry to the corrections system plays an important role in preventing transmission of infectious diseases within the facility. In theory, any inmate who is contagious for a communicable disease such as chickenpox or tuberculosis should not be admitted unless the facility has the capability to care for the inmate safely, such as by placement in a negative-pressure room.

Inmate medical records are similar to those found in any clinical setting. There are sections for clinical orders, progress notes, and clinical laboratory information. HIV status and viral load will be documented if available. Also contained in the medical record is a plan of care describing educational needs and education given, dental evaluation, medication administration records, consultations, and immunization status. Chronic disease follow-up visits should be determined, with the time frame for the visits based on the worst degree of control identified. Although standard infection prevention practices should be used in the corrections setting, some population-specific considerations are addressed in this chapter.

BLOODBORNE PATHOGENS

Forty-seven states, the District of Columbia, and the Virgin Islands have drug paraphernalia laws that lead to criminal penalties for the manufacture, sale, distribution, possession, or advertisement of any item used to produce and consume illegal drugs. The corrections system has a much higher proportion of drug users than the general population. In addition to issues of possession, drug users run afoul of the law when they commit other crimes to get money to buy drugs. Because of the prevalence of ongoing high-risk behavior in this population, including needle sharing for drug injection, multiple sexual partners, and ongoing sexual activity within the prison, previously uninfected inmates are at high risk of infection with HIV and HCV during their incarceration. Ultimately, this contributes to further transmission of HIV and other STDs within the community when prisoners are released.

According to the Centers for Disease Control and Prevention (CDC), at least half of the new cases of HIV infection occur in people 13 to 24 years of age.[10] Youth who enter the corrections system may have a higher prevalence of infection due to intravenous drug use, hormonal changes, or lack of physical maturity. Incarceration may present an opportunity to identify newly infected individuals; however, treatment regimens are increasingly complex and costly, and the inmate may be released before treatment or public health interventions can be put into place. When younger adults move through the corrections system, it is critical to ensure that STDs and HIV treatment is monitored and continued. Infection with STDs indicates increased risk of HIV. Women aged 15 to 25 have the highest rates of STD infection; their partners are often men 24 to 30 years of age. If unrecognized HIV infection is not treated, severe immunosuppression may occur, resulting in increased risk of acquiring other diseases such as tuberculosis. Recommendations from the CDC recognize the unique nature of this population and stress close collaboration with local and state public health personnel to prevent and control HIV and hepatitis infection among inmates, released inmates, and the communities to which they return.[4]

Although the prevalence of HBV infection has significantly decreased over the past decade as a result of vaccine usage, disease prevalence in the correctional setting is higher than in the community due to chronic cases. The CDC recommends HBV vaccination of all detained adolescents and adults who receive a medical evaluation in a correctional facility without documentation of prior immunization or immunity.[4] As seen in the general community, the prevalence of HCV in the correctional setting has

increased significantly, with shared needles during intravenous drug use and tattooing with HCV-contaminated objects being the primary risk factors. As there is no vaccine available to prevent infection with HCV, emphasis must be placed on preventing exposure.

STANDARD PRECAUTIONS

Healthcare and security staff are at particular risk of occupational exposure to body fluids due to the potentially violent nature of the setting and the high prevalence of infected inmates. There are approximately 750,000 employees in this setting, two-thirds of whom are security staff. It is essential that both medical and nonmedical staff receive initial and ongoing education regarding Standard Precautions. Special emphasis should be placed on proper hand hygiene and the effective use of personal protective equipment (PPE). Education should also be provided to inmate workers assigned to handle contaminated laundry or those assigned housekeeping duties in medical areas that may have exposure to blood and other potentially infectious materials. Although appropriate PPE should be available for immediate use wherever it may be needed, it may be necessary to assess securing this equipment so that it will not be available for inmates to use for nonmedical purposes. An exposure control plan, consistent with the latest recommendations from OSHA and the CDC, should be implemented.

OCCUPATIONAL EXPOSURE TO BLOOD AND BODY FLUIDS

Healthcare personnel (HCP) exposures generally mirror those seen in any healthcare facility. Correctional officers are more likely to have exposure to sharp objects (e.g., razors, weapons, and tattoo devices), mucous membranes, and nonintact skin exposures during altercations and situations involving the use of force. Because of the high prevalence of bloodborne pathogens among inmates, all employees should be vaccinated against HBV. Postexposure prophylaxis for HIV should be provided to anyone with a significant percutaneous exposure or upon request.

An ongoing concern for correctional staff is potential exposures to body fluids during the course of physical altercations. It is impossible to adequately predict when such an exposure may occur. Wrestling with an inmate while in gown and mask is impractical. Medical providers must remain calm and consistent when evaluating potential exposures. Consistently applied postexposure protocols must be developed and disseminated for all staff to follow and must be in compliance with local and state laws regarding the testing of source blood and patient confidentiality regardless of whether the exposure is inmate–inmate, staff–inmate, or staff–staff.

SAFE HANDLING AND DISPOSAL OF SHARP INSTRUMENTS

It is important for medical personnel to work closely with security staff members regarding the selection, handling, and disposal of sharp instruments. Any recommendations for engineering or work practice controls for handling and disposing of all sharp instruments must also be in compliance with current federal guidelines. Considerations include:

- Medical staff must be aware that any sharp object can/will be stolen and potentially weaponized, including paperclips, ink pens, pencils, staples, Styrofoam cups, and any medical sharps, including those engineered for HCP safety. Any equipment can be disassembled for misuse.
- Access by inmates to sharps such as phlebotomy equipment or sharps containers must never be allowed. Only the supplies that will be used on the patient at that moment should be available to the HCP.
- Needleless systems, oral rather than intravenous, and urine or oral fluid tests should be substituted for blood tests whenever possible.

Safety considerations of the HCP who must use this equipment cannot be compromised; correctional staff should be present and watchful whenever sharp equipment must be used. Safer sharps devices that have built-in features such as sheathing devices, blunted surgical needles, and retractable needles and blades should be considered. However, many of these safety syringes use a spring-loaded system that utilizes sturdy gauge wire, which may pose a security concern since the syringes can be easily disassembled.

COUNSELING AND TESTING SERVICES

The purpose of hepatitis and HIV counseling and testing is to provide early identification of the disease, initiate interventions (such as education, treatment, or vaccination), prevent further transmission, and reduce the progression of disease.[4] HIV testing should be conducted in compliance with state and local laws and with the informed consent of the patient. Some states and the federal system have mandatory HIV screening of all entering inmates. Although most states will test individuals who are symptomatic or who request HIV testing, some states test those who have been in an incident or upon release. Whether HIV testing is mandatory or voluntary, pretest and posttest counseling should be provided to all inmates. To protect patient confidentiality regarding HIV status, detailed policies addressing the protection and disclosure of HIV-related information, including partner notification, are necessary. As was demonstrated in a cross-sectional analysis,[11] the benefits of early HIV testing in correctional settings identified that testing in jails finds detainees in early disease progression and does not increase pharmacy costs. The CDC has recommended that correctional facilities establish criteria for the treatment of HCV-infected inmates.[4]

EDUCATION AND PREVENTION OF BLOODBORNE PATHOGENS

In the absence of a vaccine or cure, education is especially vital for the prevention of HIV and HCV infection and transmission. There are numerous grant-funded groups willing to provide educational counseling in jails and prisons, as correctional settings provide a unique opportunity to offer programs to a captive, high-risk population that might otherwise be inaccessible. An HIV/HCV education program should be comprehensive and appropriate for its targeted audiences, which include the medical and nonmedical staff as well as inmates. Programs that are culturally and linguistically appropriate will benefit not only the incarcerated population but also the communities to which they return. HIV/HCV prevention education programs should provide explicit information on risk-reduction behaviors (including needle hygiene and safer sex activities), and situational education that prepares the inmate to deal with the scenario before it escalates to risky behavior. Peer-taught programs, which are the most effective, require an environment in which HIV-infected inmates are accepted. Correctional officers should be trained in the general principles of infection prevention, including bloodborne pathogens and their transmission, and how to constructively manage exposure incidents.[4]

HOUSING

The integration of HIV-infected inmates into the general population, if their physical condition permits, generally provides them with equal access to all programs available to noninfected inmates but may also expose them to harassment. Medical conditions related to HIV infection, such as dementia, weakness, and chronic diarrhea, may require special housing considerations as recommended by the medical staff. The NCCHC and the APHA oppose segregated housing for asymptomatic HIV-positive inmates.[6,7] Some prisons have established drug-free units (DFUs), which are separate living units within the facility. Since illicit drug use still occurs in the prison setting, prisoners not using drugs may experience substantial

difficulties. DFUs focus on limiting the availability of drugs and house prisoners that have volunteered to sign a contract promising to remain drug-free. [12]

HARM REDUCTION

Regulations governing prison conduct are often barriers to disease prevention. Despite a setting with the priority of "security first," there are issues related to personal hygiene of inmates including access to showers, clean clothing and bedding, participation in risky behaviors such as sexual activity (consensual sex, rape, gang rape, and survival sex), drug use, tattooing, and lack of facility cleanliness.[13] Although the public health perspective holds that all individuals should have the knowledge and means to protect themselves from disease transmission, the vast majority of correctional facilities prohibit condom possession or distribution and needle exchange programs; inmates who engage in risky sexual and drug use activities are unable to protect themselves from disease transmission. Unlike many other countries, no U.S. correctional system distributes bleach or clean needles to inmates.[11,12] An analysis of evidence regarding risk behaviors in correctional centers identified condom distribution, opioid substitution therapies, and needle and syringe programs as being effective at reducing HIV risk behaviors.[14]

In many of the situations in which harm-reduction materials have been introduced, the implementation has involved outside groups. By using this approach, the correctional system will not appear to violate laws against the high-risk behaviors in that setting. For the same reason, it may be useful to make arrangements to have outside agencies provide harm-reduction education for offenders. Providing harm-reduction education while prisoners are incarcerated may provide secondary benefits to the community. Prisoners often want to celebrate their release by engaging in activities that were not allowed in prison. A study of Latino inmates in a California prison found that 51 percent reported having sex in the first 12 hours after release. Inmates also indicated the desire for "pure" (condomless) sex. In addition, 11 percent reported injecting drugs in the first day after release.[15]

TUBERCULOSIS

The dramatic increase in tuberculosis beginning in the late 1980s occurred largely in urban centers where HIV infection rates were high. This was especially true among individuals dually infected with HIV and *M. tuberculosis* who have a 30- to 40-fold increased risk of progression to tuberculosis. Tuberculosis has always been of concern in the correctional setting where individuals at high risk of disease are housed in overcrowded conditions in poorly ventilated facilities. The occurrence of recent outbreaks of multidrug-resistant tuberculosis (MDR-TB), especially in overseas correctional settings such as the former Soviet Union, resulted in infection and death of staff and inmates. This further underscores the importance of a comprehensive and effective tuberculosis control program in this setting.

Strategies to control tuberculosis must consider the nature of the correctional system, including the revolving door between prisons and the community. During 1997, an estimated 40 percent of all those in the United States who had active tuberculosis that year passed through a correctional facility.[5] In one urban jail in Illinois, 43 percent of inmates with a positive skin test were discharged before follow-up evaluation was completed.[16] Jails are important reservoirs of tuberculosis, which may affect the surrounding communities. Because there may be less inmate turnover in state and federal facilities, different strategies might be more efficient and cost-effective in these settings. All correctional facilities should work closely with appropriate community and state agencies for effective control and follow-up of released inmates.

Recent federal guidelines on tuberculosis recommended that each healthcare facility identify an individual responsible for the tuberculosis control program; this responsibility may be assigned to the IP.[17]The designated person should be defined in the institution's TB control plan.

SCREENING

CDC guidelines for tuberculosis screening using the Mantoux method consider a 10-mm reaction to be positive in the correctional setting unless an individual is HIV infected or has recently been in contact with a person with active disease. In these circumstances, a 5-mm reaction is considered positive.[18]The

Federal Bureau of Prisons recommends that all federal prison inmates with a tuberculin skin test greater than 5 mm be referred to a physician for evaluation. [17]

In 2001, the Quantiferon-TB test was approved by the U.S. Food and Drug Administration (FDA) as an aid for detecting latent tuberculosis infection. This is a blood test that detects interferon gamma in response to *M. tuberculosis*antigens. The CDC recommends using the Quantiferon-TB test for those at increased risk of latent tuberculosis infection, including residents and employees of prisons and jails.[19]

This test requires phlebotomy and processing within 12 hours of collection. However, it provides results faster than the tuberculin skin test. Mitigating factors against more common tests are the cost and limited availability of labs that perform the testing. BCG strains and the majority of other non-tuberculosis mycobacteria do not harbor ESAT-6, CFP-10, and *M. tuberculosis* 7.7 proteins; thus, patients either vaccinated with BCG or infected with most environmental mycobacteria should test negative.

One urban jail has found miniature chest radiography to be most efficient and cost-effective in identifying active tuberculosis in its setting; results are available within hours.[10]There are no universal

requirements for chest x-rays to be performed to rule out tuberculosis on admission to a facility or on a routine basis.

SURVEILLANCE

The tuberculosis control program developed for each correctional institution should include surveillance and monitoring systems used after the initial screening. Monthly statistics should be collected on the following: tuberculosis infection rate of new admissions, number of skin tests performed but not read, skin test conversion rates of inmates and staff, and the number of cases of active tuberculosis disease cases. It may take up to 2 years after the initiation of a tuberculosis surveillance program to establish reliable statistics on tuberculosis infection, disease, and skin test conversions. With the worldwide increase in MDR-TB, which includes strains resistant to all first-line antibiotics used to treat extremely drug-resistant tuberculosis (XDR-TB), ongoing data collection and periodic evaluation of rates could identify an undetected problem. Time trending may also indicate the need for different or additional tuberculosis control strategies.

DIAGNOSIS

Patients who are being evaluated for tuberculosis must be housed in appropriately ventilated isolation rooms consistent with airborne infection isolation (AII) criteria used in healthcare settings. Any inmate who has symptoms of active tuberculosis should receive a chest radiograph and have sputum collected for smear, culture, and drug-susceptibility testing. Sputum collection must be performed according to specified procedures and CDC-recommended tuberculosis isolation precautions.

CHEMOPROPHYLAXIS

Preventive therapy, based on the most current guidelines, is recommended for individuals identified with *M. tuberculosis* infection.[20] Directly observed therapy (DOT), even in correctional systems with self-administration of medication programs, provides for the monitoring of compliance with the chemoprophylactic regimen and is the preferred method of medication administration. When providing DOT therapy, it is imperative to ensure that the inmate has swallowed his or her medications. Not swallowing, hoarding, and then overdosing on prescribed medications is not uncommon in this population. When the inmate is released, his or her close cooperation with the local health department is imperative to maximize chances of success with treatment. Inmates co-infected with HIV should be managed by clinicians with expertise in treating these infections.

TUBERCULOSIS ISOLATION

Any individual suspected of having tuberculosis requires AII; PPE should be used by staff until a diagnosis is determined. Engineering controls, including negative pressure and air exhaust directly to the outside, away from any air intake device, should be implemented in accordance with local, state, and federal regulations. When ventilation systems are not appropriately constructed, a high-efficiency particulate air filter system may be used but should not be accessible to the inmate. It is the responsibility of the designated tuberculosis control person to ensure that effective AII is provided. If tuberculosis isolation is not available within the correctional setting, the inmate who is suspected of having tuberculosis must be sent to a facility that has provisions for isolation of a suspected tuberculosis patient. Specific guidelines for AII precautions, including engineering and work practice controls and PPE for suspected or confirmed active tuberculosis, should be described in each institution's tuberculosis control plan.

When evaluating a correctional facility for appropriate engineering controls, prisons should adhere to the same standards of validation of negative airflow that noncorrectional facilities must meet. Newer facilities will have engineered negative-pressure rooms that may have digital readout devices. Rooms should be tested daily when occupied by an inmate with suspected or active tuberculosis and have airflow measured by a qualified individual on a routine basis. It is important to observe the relationship of the intake and outflow vents; in an endeavor to prevent inmates from removing vent covers, both vents may be located on the ceiling. Unless there is an excellent diffuser, effective air circulation may be minimal. Vents and vent ducts should be clean and free from dust. Evaluation may involve consultation with the facility engineer to validate where the air from the isolation room is vented.

PERSONAL PROTECTIVE EQUIPMENT

PPE is considered to be a less effective intervention than administrative and engineering controls. All medical and nonmedical personnel who enter an occupied AII room must wear a particulate respirator that meets current federal guidelines.[21] Officers or deputies who transport individuals with suspected tuberculosis should wear the recommended respirators and the inmate should wear a surgical mask while being transported. If appropriate safety devices are in place in the vehicle, windows may be opened for additional air diffusion purposes. Other circumstances that require a particulate respirator must be specified in the facility's tuberculosis control plan. These respirators are to be worn according to the manufacturer's instructions. Although the use of powered air-purifying respirators (PAPR) is acceptable, their use in the correctional setting may be of limited value. Vision and mobility may be compromised because the equipment is battery-operated and consists of a half- or full-face piece, breathing tube, battery-operated blower, and particulate filters (HEPA only). If necessary, a face shield in

conjunction with a half-mask PAPR respirator or fluid-resistant N95 respirator and goggles may be used for protection against body fluids.

A policy must be developed for all personnel, including males with facial hair who may be exposed to inmates with suspected or confirmed *M. tuberculosis* infection. A respiratory protection program including fit testing must be in place; education that meets OSHA guidelines must be provided annually to all staff who may wear respiratory protection.

CONTACT INVESTIGATION

Staff and inmates who have had unprotected exposure to a patient with active tuberculosis should be identified and evaluated. Facilities that have received transferred inmates who were among the exposed contacts should be notified so that those inmates may receive the appropriate evaluation. As such outbreaks might be large, consideration should be given to enlisting resources from other local, state, or even federal agencies.

EDUCATION

Although tuberculosis may be a difficult disease to understand, understanding is essential for an effective tuberculosis control program in the correctional setting. Inmates and medical and nonmedical staff should receive accurate information on infection and disease (symptoms of the disease and ways the disease is transmitted), in a format that is appropriate in content and language (where possible) to the needs of each group. Individuals infected with *M. tuberculosis* and/or who have developed active disease should receive education on the importance of compliance with their therapy. Educational materials provided to inmates may not contain staples. Even with accurate and timely education, the facts may be insufficient to allay fears among inmates or correctional staff. It is important that prison facility administrators have full understanding and reinforce the appropriate prevention and precautionary messages; their assistance should be enlisted ahead of the presentation of the staff program.

COLLABORATION WITH PUBLIC HEALTH AGENCIES

Collaboration with the local or state public health agencies for all aspects of the tuberculosis control program is useful and essential. Reporting of active disease must be prompt to ensure that appropriate contact investigations, including in the community, can be conducted in a timely fashion. Inmates can be discharged at any time—during screening, a contact investigation, or during chemotherapy—but still should be linked to the appropriate community agency for needed follow-up services. Before discharge, follow-up appointments should be arranged and the inmate and his or her parole officer be made aware of these arrangements. All diagnostic and treatment information should be shared with the public health department to ensure that appropriate records are available once the inmate is released into the community. If the former inmate is admitted to a local hospital, access to prior treatment information is very helpful for clinicians.

SEXUALLY TRANSMITTED DISEASES

Previous studies of incarcerated populations have reported high rates of STDs.[22,23,24]It has been

estimated that up to 25 percent of males and 90 percent of females have been sexually abused prior to incarceration. Large numbers of these individuals may have engaged in risky behaviors such as prostitution as a way to raise money to support a drug habit or been a member of a pimp's "stable," where they may have perceived themselves as powerless to leave the situation. Despite guidelines and recommendations to screen inmates for STDs, inmates may be released without STD screening and/or treatment because the median length of stay in a jail is less than 48 hours. Collaboration with local and

state agencies is important for assessing the feasibility of screening new admissions based on prevalence rates in the community. Urine tests for chlamydia and gonorrhea facilitates screening in the correctional setting. Observational studies have found that screening and treatment programs for chlamydia have the potential to reduce prevalence for high-risk populations.[23] Furthermore, it was determined that treating male prisoners for chlamydia caused a decrease in the rates of the disease in female high-prevalence populations.[24]

Rapid screening and treatment protocols have been developed and effectively implemented in some correctional facilities. STD infection in the presence of concurrent HIV may have altered manifestations and treatment requirements. Individuals with STDs, with or without concurrent HIV infection, need information on preventing disease transmission. Education should be provided to all inmates (especially new admissions and those to be soon released) on safe sex practices and reproductive health. Unfortunately, education may not lead to behavioral changes if the person is released back to the same setting where problems previously occurred.

Treatment should be based on current guidelines.[25,26] Cases should be reported to the appropriate local and state agencies for timely and effective contact investigation. Patients released before completion of evaluation and treatment should be provided with a follow-up appointment at the time of release. The medical team may not be aware of a pending release due to the rapid movement of inmates. Prompt notification of the local health department and the parole officer may provide the only chance for follow-up and/or treatment of those inmates.

VACCINE-PREVENTABLE DISEASES

General recommendations of the Advisory Committee on Immunization Practices (ACIP) for routine immunization of healthy and immunocompromised adults should be followed for adult inmates. This includes providing a tetanus diphtheria vaccine every 10 years, pneumococcal vaccine (according to the guidelines), and annual influenza vaccine. Because antibody response to pneumococcal disease and other vaccine-preventable infections may be suboptimal in symptomatic HIV infection, immunizations such as the seasonal influenza vaccination should be offered to HIV-infected inmates on a priority basis.

Juvenile halls have their own immunization screening and administration requirements. Immunizations of children and adolescents in correctional facilities should follow recommendations of the American Academy of Pediatrics, ACIP, and the American Academy of Family Physicians.[27] Vaccines for this population are often available free through federal programs.

Because of the overcrowding common in the correctional setting and because many inmates had limited access to healthcare before incarceration, they may not have received the recommended childhood immunizations. Therefore, outbreaks of vaccine-preventable diseases may be a relatively frequent occurrence in this environment. Outbreaks of measles, mumps, and rubella that continue to occur in the unvaccinated U.S. general population may be reflected or magnified among the incarcerated population. In outbreak situations, consultation with public health advisors is recommended because of the complexities and speed of interventions needed for controlling vaccine-preventable diseases.[28] Each correctional system should develop policies and procedures for mumps, rubella, and measles for medical and nonmedical staff and for inmates. Immunization with the triple-valent MMR vaccine is most efficient for the prevention of all three diseases. In the event of an exposure to or outbreak of measles, mumps, or rubella, the health department may place a quarantine on the facility or sections of the facility and may mandate immunization of all staff and inmates who lack proof of immunity. Because of

the high rates of recidivism, correctional facilities need to have a system to be able to identify inmates who were immunized during a previous incarceration.

In the event of an outbreak of influenza, guidelines are available for its control in the institutional setting.[29] Specific problems include overcrowding (including minimal space between bunks), poor ventilation, and lack of easy access to hand hygiene. Whether outbreak control measures are implemented depends on the severity of the outbreak, control measures required, and the availability of resources to implement such measures as antiviral treatment and prophylaxis if ordered.

VARICELLA

An estimated 90 percent of young adults have had chickenpox or received varicella vaccine.[30]

Susceptibility to varicella virus is higher in foreign-born individuals, especially those from tropical climates. Although verbal history of prior infection is not very reliable, many offenders are probably immune. In the setting of an exposure investigation, testing for the antibody may be considered, especially in populations at high risk, such as those who are HIV-infected. Varicella vaccine may be indicated for susceptible individuals at high risk for infection.

As in medical settings, a suspected case of varicella requires Airborne Precautions until the diagnosis is ruled out or the individual is confirmed to be no longer contagious. Shingles (localized herpes zoster) requires Standard Precautions but nonimmune inmates or staff should not be exposed. Minimally, inmates with shingles should have their lesions covered. Control measures to minimize transmission in the correctional setting are a challenge, especially in facilities where inmate turnover is rapid. Measures include cohorting of nonimmune exposed individuals from 10 days after the first exposure until 21 days after the last exposure and limiting inmate movement and visits. If cohorting is used, the heating, ventilation, and air conditioning (HVAC) system should be checked to ensure that air is not discharged into an adjoining wing containing nonexposed persons. The CDC has published recommendations for the vaccination of susceptible inmates and staff that are not immunocompromised.[31]

The occupational health program of the correctional system should evaluate and vaccinate susceptible employees. Staff can be educated regarding varicella infection and vaccination. Referral of facility staff to the local health department or a private physician may be considered.

OTHER INFECTIOUS DISEASES

Enteric Disease

In the correctional setting, gastrointestinal infections most frequently present as foodborne outbreaks, opportunistic infections in association with HIV infection, or casual transmission through a fecal-oral route. Inmates often store food unrefrigerated in their cells for later consumption. Inmates provide much of the labor in the kitchen and dining hall, where hygiene is supervised by either another inmate or correctional staff who may not be familiar with food safety tenets. As with investigating any foodborne outbreak, it is imperative to interview all kitchen workers for evidence of current or recent diarrheal illness as soon as possible. Also, hands of workers should be examined for any long nails or organic material. Personnel should observe Standard Precautions when treating inmates with a diarrhea-associated illness. Contact Precautions may be required for any inmate unable to maintain good hygiene. This includes a single room with individual hand washing and toilet facilities if possible. Instruction on good personal hygiene is necessary. Contaminated laundry should be handled using

Standard Precautions and according to routine protocol, regardless of the suspected presence of infectious agents.

Norovirus

Outbreaks of norovirus have been increasingly identified in corrections facilities and can be prolonged and severe. Norovirus is characterized by both a low infectious dose and a high attack rate. Immunity may last only months. The sudden onset of illness, including nausea, vomiting, watery diarrhea, and stomach cramping, along with high attack rates, generally help to identify this infection. Laboratory confirmation of a few cases early in the outbreak is helpful. Noroviruses are readily spread from person to person by fomites and from contaminated environmental surfaces. Contaminated toilet areas will magnify the outbreak. Norovirus is persistent in the environment until removed by thorough cleaning with bleach or disinfectant with a norovirus claim.

Although symptoms typically last a day or two, norovirus particles can be shed for more than a week after symptoms resolve. It is critical to restrict inmates with norovirus symptoms from kitchen duties for an extended time period. Essential strategies to curb outbreaks include:

- Having medical personnel go cell to cell to query inmates for the presence of symptoms
- Limiting inmate movement through the facility, including suspending indoor group activities such as visitation, school, and religious services[32]
- Confining symptomatic inmates to quarters until they have been asymptomatic for at least 48 hours. This may include feeding sick inmates in their cell, dorm, or housing unit
- Not mixing exposed and unexposed populations
- Although hand washing is the most effective strategy to prevent norovirus transmission, use of disposable hand towelettes, or supervised use of waterless hand cleaners, may also be implemented prior to meals if hand-washing facilities are not accessible.

The facility may wish to consider forming rapid-response "vomit squads" that can be educated to cordon off, clean, and disinfect contaminated areas to minimize exposures. Surgical masks should be worn when performing cleaning activities. Dining areas should be cleaned and then wiped with bleach solution between seatings. Added cleaning requirements for the dining hall may impede tight time schedules where large numbers of inmates must eat quickly prior to being escorted back to their housing pod. Routine housekeeping efforts should be intensified, including the cleaning of walls, floors, tabletops, handrails, sinks, toilets, doorknobs in day rooms, communal restrooms, dining facilities, and showers. Bedding and clothing of infected inmates should be laundered using a chlorine bleach product and/or dried in a hot dryer.

It is imperative to enlist correctional staff when planning prevention and control measures. A factor that may interfere with implementation of the activities listed above is the difficulty to limit inmate movement; the stoppage of movement will impact not only that facility, but all other jails or prisons that feed that prison. Inmates, when put on lockdown, will pressure other inmates to deny symptoms in an attempt to end the quarantine sooner. Although alcohol-based hand sanitizers may be used in addition to handwashing to prevent norovirus transmission, they should not be used as a substitute for handwashing. Furthermore, if alcohol-based hand sanitizers are available, inmates might ingest liquid/gel products supplied in dispensers.

Foodborne Outbreaks

A foodborne outbreak is usually recognized by the abrupt occurrence of illness associated with nausea, vomiting, or diarrhea in a group of individuals associated with foods eaten by ill inmates. Foodborne outbreaks may be related to institutional or contraband food preparation and storage. When improper food preparation is involved, the number of cases will be large. In a large prison setting in which different housing areas or dorms may eat at different times, the location of the ill inmates may help in identifying the areas for investigation. When contraband food is involved (often chicken or other poultry products), the number of cases probably will be limited. Furthermore, monitoring temperatures and training staff in proper handling of food coupled with early diagnosis of outbreaks may limit the spread of illness.[33] The local or state health department should be notified of the outbreak. Health department staff can provide guidance, personnel, or occasionally both, for conducting the outbreak investigation. Laboratory testing may be available through the local or state health department. Appropriate food preparation and sanitation practices are necessary for the prevention of foodborne illness. Correctional institutions may have different protocols for inmate food-handler clearance. These should be in compliance with local and state regulations. Infection with a bloodborne pathogen or latent *M. tuberculosis* infection is not a reason for excluding an inmate from kitchen work. Inmate food-handlers should receive education on principles of basic food sanitation and safety principles.

Obstacles to inmate education include lack of a stable inmate workforce and/or lack of motivation to comply with added rules.

Food Safety

In addition to maintaining food temperatures within safe ranges, there are two essential practices for the prevention of foodborne illness. The first practice is cleanliness in the kitchen, including properly sanitized equipment, foods held and stored at recommended temperatures, and good personal hygiene in the kitchen staff (e.g., clean clothes and frequent handwashing). The second practice is daily inspection of the kitchen workers to include querying for current skin lesions, upper respiratory tract infections, and diarrheal illness. Workers answering affirmatively should be excluded from kitchen duty until the condition is resolved. Documentation of food temperature checks, cleaning practices, and inspections of kitchen workers may be maintained in a daily logbook. Inspection of kitchen workers and documentation of food safety practices may be the responsibility of correctional officers or contract personnel. Education of appropriate workers or inclusion in contract language may be needed. Ongoing education regarding the practice of good personal hygiene is essential. If vending machines are available in the facility, policies should be implemented to address proper management of these machines, especially for routine cleaning and appropriate refrigeration.

Ectoparasite Control

As in any congregate living setting, correctional institutions should have procedures in place to prevent the transmission of communicable infestations. If an inmate is infested at the time of intake, they should be kept separate until provided with the appropriate treatment. If a single case of pediculosis or scabies is identified in a housing area, cellmates should be screened and/or treated for infestation. In a widespread outbreak, treatment of all inmates in the pod may be considered.[34,35]

In an outbreak situation, the IP should attempt to identify and eliminate the source and determine the pathways of transmission. For pediculosis capitis, hair removal practices should be investigated. Hair accessories need to be discarded or cleaned with a pediculicide and/or cleaned with hot water (130°F/54°C).

Contaminated clothing and bedding should be labeled and handled according to Standard Precautions protocols. Hot-cycle washing and drying of laundry will destroy eggs or mites. Clean clothing and bed linens should be provided after treatment. It will be necessary to work with prison administration to ensure that clean clothing and bed linens are available in light of the fact that inmates are generally issued these items once or twice per week. Screening and/or treatment of exposed staff should be provided.

Fungal Infections

Fungal infections of the body and feet can be a pervasive problem in the correctional setting. Many inmates are infected, shower drains are frequently clogged, shower shoes are not always used, and changes of socks are rare. A fungicidal agent should be used routinely to clean shower stalls, bathroom floors, gymnasium floors, and benches. Antifungal creams or powders may be given to inmates for self-treatment. Shower slippers should be available to inmates. For fungal infections occurring in prison farm workers, the farm animals should be examined and treated.

Meningitis

Meningitis caused by any bacteria or virus can create a climate of fear and panic among inmates and nonmedical staff. In studies of crowded barracks in the military, *Neisseria meningitidis*, the causative organism of meningococcal meningitis, may have high asymptomatic carrier rates in overcrowded settings such as prisons. Carriage rates have been found to be higher where beds are less than 3 feet apart,[36] as frequently occurs. Rapid identification of potential *N. meningitidis* infection is key to controlling the reaction to and potential spread of this disease.

If a case of meningococcal meningitis is diagnosed in the correctional setting, close contacts of the patient should be identified and observed for early signs of illness. Chemoprophylaxis should be limited to those the infected inmate may have been socially intimate with, including sexual contacts or those with whom eating utensils or cigarettes were shared; a population control approach may be required. In conjunction with the local health department, a decision should be made as to whether to transfer exposed inmates during their potential incubation period. Other activities may include identification of inmates who may have been transferred to other correctional systems or by release back to the community. The health department can often assist with providing preventive medications. Cases of meningitis should be promptly reported to appropriate local and state agencies.

Antibiotic-Resistant Infections

Infections due to antibiotic-resistant bacteria, particularly MRSA, have been commonly associated with hospitals and nursing homes. Newer strains have recently been identified as an increasingly frequent cause of skin and soft tissue infections in community settings, including corrections facilities.[37,38,39]

Although these infections were often initially mistakenly identified as spider bites, more recent information about community-associated skin and soft tissue infections is widely available.

In the corrections setting, investigation of recent MRSA outbreaks identified three factors associated with transmission:

- Barriers to inmate hygiene, such as limited access to soap or inappropriate use of bar soaps, behavioral problems among inmates, and inadequate or delayed laundering of clothing. New alcohol-based hand rubs have been difficult to introduce because of the potential for misuse of these

products. Inmates' clothing washed by hand or in bulk loads and potentially contaminated laundry might not undergo sufficiently high water temperatures or drying to eliminate bacteria.

- Barriers to medical care, including co-payments and inadequate supplies and staff for wound care
- Lack of education of both medical and nonmedical staff on issues of recognition and proper treatment, including proper use of antibiotics and high staff turnover rates, increase the difficulties of prevention and control.

Risk factors for MRSA infection include prolonged (more than 36 days) incarceration, outdoor work duty, inadequate wound care by medical staff, previous antimicrobial use, self-draining of boils, skin laceration (intentional or accidental), prison tattooing, washing clothes by hand, sharing soap, and incarceration after 2001. In response to MRSA outbreaks, many facilities have implemented programs to improve hygiene and infection control practices. Strategies should include:

- Visual skin screening on intake or the initial medical examination, skin infection screening, and monitoring by maintaining a log of skin infections
- Provision of incision and drainage or culturing suspect lesions and providing targeted antimicrobial therapy as appropriate
- Efforts to improve inmate hygiene, including education of appropriate hand and body hygiene, appropriate laundering techniques, measures to limit use of shared items, and greater availability of soap
- Improved inmate access to wound care by trained healthcare staff

Traditional hospital-based approaches to preventing MRSA transmission (e.g., placing infected persons in a separate area or eradicating nasal colonization) are not likely to be feasible in most correctional facilities. Prevention or rapid resolution of MRSA infections in inmates might be an important measure for prevention of further spread of MRSA in the community.

Respiratory Infections, Including Influenza

Because of the living conditions within correctional facilities, there is always the possibility of large outbreaks of influenza-like illness among both the inmates and staff. Guidelines for respiratory hygiene and influenza immunization for inmates and staff should be in place prior to the influenza season. Vaccination of inmates and staff at increased health risk for influenza should be prioritized. During an outbreak or cluster of infection, symptomatic inmates may be confined in a dormitory with cohorts during the illness if they do not require infirmary or hospital care. Education concerning the need for fluids is needed for the afflicted inmates and the correctional staff providing custody. Although control measures are similar in some situations, it will be valuable to obtain viral cultures to confirm a diagnosis. The public health department may be able to assist with culture materials and laboratory services.

Epidemic levels of coccidiomycosis have been especially noted among inmates with no prior exposure to desert areas (arid, dusty environments) such as correctional facilities located in California, Arizona, and Nevada. This situation is currently under investigation by the CDC; recommendations to mitigate these situations will be forthcoming.

MOVEMENT RESTRICTIONS FOR THE PREVENTION OF COMMUNICABLE DISEASES

Inmates may be moved within a facility or between facilities at any time of the day or night. Usually medical procedures include a process concerning medical hold, which can be used if it is important for

an inmate to be kept at the current facility for management of a healthcare condition. This may be necessary in many circumstances such as active infectious disease, need for a specific treatment or vaccine series, and follow-up of an exposure to infectious disease.

Movement restrictions can be applied to individual inmates or the entire population of the facility. For example, inmates may be held in place for 24 hours pending completion of treatment for scabies or lice. All inmates at a facility may be held in place until all have been vaccinated. The IP and medical staff must work closely with the correctional staff to coordinate details of any movement restrictions.

Special Considerations

ADMISSION AND DISCHARGE

New Admission Assessment

Upon admission, the following infectious diseases assessments should be completed:

- Visual inspection of hair and skin for pediculosis (*P. humanus capitis, P. humanus corporis, Phthirus pubis*), scabies, rash-related illnesses, and skin lesions
- STD screening to include clinical and laboratory examination for syphilis, gonorrhea, chlamydia, other inflammatory and ulcerative disease, and a Papanicolaou test for women
- TB screening to include Mantoux tuberculin skin test and evaluation for presence of symptoms, and a chest radiograph for those who are skin-test positive or symptomatic
- Determination of the presence of risk factors for HIV infection: substance abuse, injection behaviors including tattooing and drug administration, and multiple sex partners (refer for HIV counseling and testing)
- Screening of the skin for any lesions or soft tissue infections
- Dental screening, including visual inspection of the oral cavity, teeth, and gums, noting the presence of any gross abnormalities or oral lesions. (Many infections and communicable diseases have oral manifestations including candidiasis, the primary chancre of syphilis, Kaposi's sarcoma, genital herpes, and gonococcal pharyngitis.)

DISCHARGE PLANNING

Discharge planning for jail inmates should be initiated at the time of admission in anticipation of sudden release from the facility. Most inmates do not have access to private medical care. All inmates who will be placed on parole, their discharge planner (if available), and parole officers should be given information for follow-up with local health departments if any screening test results are positive and if further evaluation or treatment is not performed or completed while the inmate is incarcerated. Inmates receiving treatment for an infectious disease should be given information on clinics that can continue medical care after discharge along with an appointment and enough medication to last until the released inmate is seen by a clinician. In cases where active TB is identified, the local health department should be notified to arrange for follow-up care, which may include DOT. It is preferred that the inmate receive a specific follow-up appointment with appropriate community agencies for continued care after discharge. The local or state health department should be informed about inmates who are being discharged with communicable disease. If the facility knows that an inmate who is ready for discharge is homeless, appropriate housing should be identified, if possible. All of the recommendations listed above

may be worthless when an inmate is released without knowledge of the multidisciplinary medical support staff.

It is also important for inmates who have been receiving medical, mental health, or substance abuse treatment in prison or jail to continue their treatment after discharge. Without continued support after release, inmates may return to behaviors that led to their arrest.

Women's Health

Since the early 1980s, the number of women in prison has tripled. Women in prison are overwhelmingly nonwhite (60 percent). Female inmates account for nearly 7 percent of all inmates and are the fastest growing group.[40,41] More than two-thirds of women of this population are recidivists.

As mentioned, studies have found incarcerated women to be at high risk for physical, emotional, and sexual abuse, STD and HIV infections, and drug abuse, which adds to the complexity of communicable disease control in this setting. Before disease control measures are instituted, it may be prudent to verify the pregnancy status of the inmate, as a pregnancy test performed on the day of incarceration may not reflect an inmate's current status. Expanded STD and HIV education, high-risk behavior prevention programs, and drug rehabilitation programs are needed. Treatment and prevention programs should consider gender, race, and psychopathology in order to determine effective modalities to improve outcomes and prevent future infections.[42,43]

There is a growing need for prenatal services and parenting classes to be expanded. Substance-abusing pregnant women who are fearful of punitive measures may avoid prenatal care before incarceration.[44] Indeed, women have been incarcerated to prevent them from using drugs for the remaining months of their pregnancy. Women in abusive or controlling relationships may be prevented from seeking prenatal care by their partners. A prenatal screening program for HBV surface antigen should be in place to prevent perinatal transmission. If nurseries are located on-site, those services should be in compliance with all local, state, and federal regulations. The availability of AII rooms for airborne disease is essential to protect women and their newborn infants.

ENVIRONMENTAL SURVEILLANCE

Standards exist for environmental surveillance in the correctional setting.[6,7] It is important for IPs to be involved in environmental surveillance directly with (which is preferable) or by sharing their surveillance reports with correctional staff. Infection control inspections of the health service areas should be conducted at regular intervals with prepared checklists. Areas to be surveyed include general housekeeping practices, proper medical supply storage, cleaning, disinfection and sterilization practices, availability of soap and paper towels for handwashing, dental clinics and their instrument sterilization procedures, other operatory settings and their instrument sterilization procedures, appropriate handling and disposal of infectious waste, compliance with work practice controls (e.g., Standard Precautions), and all medical housing areas. Infection control inspections in nonclinical areas should be done in conjunction with responsible nonmedical correctional staff and may include housing areas, recreational areas, chapels, kitchens, other food production activities, laundry, beauty and barber shops, gymnasiums, swimming pools, and emergency equipment. Weight rooms should have policies in place and enforced for frequent cleaning of athletic equipment to control the spread of MRSA.

HAND HYGIENE

Although handwashing is widely acknowledged to be the single most important means of preventing the spread of infection, consistent application of this intervention is difficult in the correctional setting. Medical and nonmedical staff and inmate workers must understand the importance of frequent and thorough handwashing and the significance of keeping their hands away from their face and mucous membranes while they are working. Unfortunately in the correctional setting, the use of antiseptic hand gels can present problems. Any product with alcohol may be considered a security risk and may need to be stored in a locked area.

LAUNDRY

Because of the likelihood of undetected infection and disease in the correctional setting, it is recommended that all laundry be handled with Standard Precautions. Recognizing that this may not always be feasible, every correctional facility should have a protocol for defining and handling laundry. An excellent reference for appropriate handling of laundry is detailed in OSHA's eTool Laundry Module [45]at **https://www.osha.gov/SLTC/etools/hospital/laundry/laundry.html**.

MEDICAL ISOLATION

Providing appropriate types of medical isolation for inmates may require ingenuity, creativity, and a great deal of unwavering assertiveness on the part of the IP. Clear-cut guidelines should be available for all to follow. Medical isolation must always be a medical decision and is one instance where medical necessity may trump security concerns. Guidelines for medical isolation are published elsewhere.

Conclusions

The correctional setting is a challenging environment that provides the IP with many opportunities to promote and maintain a clean, safe, and healthy environment, and to encourage health-promoting behaviors in that population. The potential for infectious disease transmission exists due to conditions that include overcrowding, frequent turnover, and unsanitary conditions. The IP must be an astute observer and collegial partner in this unique setting where, because of the prevalence of HIV and other conditions, there may be unusual manifestations or patterns of infection and disease. Most importantly, the correctional setting provides access to a medically challenged population where entry into the prison system may represent the first encounter with formalized healthcare and the opportunity to provide needed diagnostic and treatment services along with educational, counseling, and support services, which will ultimately have an effect on the public health of the community. The IP should actively work in a multidisciplinary fashion with correctional custodial and parole staff, public health departments, and community groups and agencies to improve the health of the inmates and secondarily the communities to which they will return.

Future Trends

The current pattern of incarceration of large numbers of nonviolent offenders for extended periods of time, specifically substance abusers, is likely to change in the United States as the discussion of drug legalization may represent a major paradigm shift in drug policy at the state and federal levels of government, and greater availability of effective substance abuse programs. This may provide relief in the future for the correctional system given budget cuts at the community, state, and national levels for drug treatment and social and support services such as community programs for youth. Research to identify and validate best infection prevention and control practices in the correctional setting is needed.

International Perspective

Among developed nations, the United States has the highest rate of incarceration. Nations internationally are reconsidering their drug policies with regard to the nonpunitive management of nonviolent substance users, as well as making available harm reduction interventions that include promoting condom usage, needle and syringe exchange, and bleach programs.[46,47]

The World Health Organization (WHO), the United Nations (UN) Office on Drugs and Crime, and the UN AIDS program (UNAIDS) have scaled up actions in other countries to assist implementation of HIV programs in prisons. Amnesty International and Human Rights Watch provide some international oversight of incarcerated individuals around the world.[44,48,49]Among their recommendations are using female-only prison guards for female inmates, especially in their living and toileting areas, prohibiting the shackling of women prisoners during childbirth, and protecting children in detention facilities. The United States is in violation of all these recommendations as well as having an increased trend of sentencing children as adults and housing them in adult facilities. Renewed emphasis on HIV and broader health issues in prisons suggests that "public health can no longer afford to ignore prison health."[50]Because protecting the health of prisoners also benefits prison staff and the community, it is essential to provide sufficient resources to address these issues.

Supplemental Resources

American Correctional Association (ACA). Available at: **http://www.aca.org**. The ACA is the oldest and largest international correctional association in the world.

Federal Bureau of Prisons. Available at: **http://www.bop.gov**. This site provides a wealth of information and statistics on inmates in correctional settings.

National Commission on Correctional Health Care (NCCHC). Available at: **http://www.ncchc.org/**. The mission of the National Commission on Correctional Health Care is to improve the quality of healthcare in jails, prisons, and juvenile confinement facilities.

World Health Organization (WHO). Available at: **http://www.who.int/en/**.

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Child Care Services

Author(s): Carol McLay, DrPH, BSN, RN, CIC
Infection Prevention Consultant

Lexington, KY

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Abstract

An increasing number of children worldwide attend child day care, especially infants and toddlers. Compared with children cared for in their own homes, children in child care centers develop infectious diseases more frequently. These diseases can spread quickly among the children in the child care setting and to child care staff members, family members, and the community, and they may affect the healthcare delivery system. Adherence to appropriate hand hygiene practices and immunization recommendations are the most important factors for reducing disease transmission in child care settings. Although every state regulates out-of-home child care, enforcement is directed toward nonresidential child care centers rather than residential family child care homes. This chapter summarizes the epidemiology of infections observed in child day care, prevention and control measures, and regulations relevant to out-of-home child care. It provides resources for infection prevention professionals who may be called on to provide consultation.

Key Concepts

- Child day care is increasingly common and provided in a variety of settings, from individual homes to large centers.
- Out-of-home child care is regulated in every state; regulations, licensing requirements, and inspections vary from state to state.
- Infectious diseases occur with increased frequency in child care centers and may spread to staff members, family members, and the community.
- Infection prevention focuses on hand hygiene, hygienic diapering and handling of bodily fluids (mucus, blood, vomit), environmental decontamination, maintaining high immunization rates, and attendance restriction policies.
- National Health and Safety Performance Standards provides resources to child care centers on quality health and safety practices and policies that should be followed in child care settings.

Background

This chapter summarizes the epidemiology and basic issues that the infection preventionist may need to address in the child care setting. Effective infection prevention is often challenging in a child care setting because infants and young children are often partially or totally dependent on caregivers for management of body fluids. Infections are readily transmitted due to proximity of the children and the unhygienic nature of children's habits, such as placing toys and hands in mouths, touching each other during play, and failing to wash hands after toileting. Effective measures to prevent the spread of infection in child care centers include hand hygiene; special attention to hygienic diapering and handling of body fluids such as mucus, vomit, blood; exclusion policies for specific symptoms and diseases; immunizations; and cleaning of environmental surfaces. Infections in child care centers cause not only significant morbidity but also impose a community burden from missed work by parents. It is estimated that 52 percent of employed parents lack access to at least five paid sick days to care for a sick child.[1]

Parents without paid sick days are more than twice as likely as parents with paid sick days to send a sick child to day care or school, which can further compound the issue of disease transmission.[2]Child care centers may also contribute to the dissemination of disease into the community; reductions in infectious disease transmission within child care centers may improve the health of children, staff, and the surrounding community.

Basic Principles

Child day care centers are licensed nonresidential facilities providing day care for 13 or more children. Year-round day care is provided commonly for infants through age 4 or 5 years. During school vacations, many child care centers also operate "camps" for children in primary grades up to 11 or 12 years old. Family child care homes provide care and education to a maximum of 12 children at a time in a residence that is usually the home of one of the care providers. A facility for ill children provides care for one or more children who are excluded temporarily from their regular child care setting for health reasons. A facility for children with special needs offers specialized care and education for children who cannot be accommodated in other types of child care centers.

Out-of-home child care is regulated in every state; however, regulation enforcement is primarily directed towards center-based child care. Many states do not require licensure or regulation of family child care homes. Nonregulated providers are not obliged to meet state child care regulations and are not subject to enforcement activities. Licensing and regulation information for each state is available on the website of the National Resource Center for Health and Safety in Child Care and Early Education.[3]

"Child care center" (CCC), as used in this document, refers to any setting providing day care away from the child's home. The term "caregiver" refers to any staff in the CCC directly caring for and having hands-on contact with the children. In this document, the terms "caregiver" and "staff" are used interchangeably. "Parent," as used in this document, applies to mother, father, or guardian.

EPIDEMIOLOGY AND CONTROL OF INFECTIOUS DISEASES

It is estimated that 3.5 million children younger than age 5 attend an organized care setting while their mothers are working.[4]Infants and young children who are cared for in a group setting have an increased rate of communicable infectious diseases and a higher risk of acquiring antimicrobial-resistant organisms. Prevention and control of infection in CCCs is influenced by a number of factors:

- Health status, personal hygiene practices, and immunization status of caregivers
- Environmental sanitation
- Food-handling procedures
- Age and immunization status of children
- Ratio of children to caregivers
- Physical space and quality of facilities
- Frequency of use of antimicrobial agents in children
- Adherence to Standard Precautions for infection control[5]

ENTERIC DISEASES

Enteric bacteria, viruses, and parasites are easily transmitted in CCCs because of the close personal contact and unhygienic habits of young children. The primary enteric organisms implicated from outbreaks include *Shigella*spp., rotaviruses, adenoviruses, noroviruses, *Escherichia coli*O157:H7, *Giardia intestinalis, Crytosporidium*spp., and Hepatitis A virus (HAV).[5,6,7,8]Organisms are spread directly from person to person by the fecal-oral route or indirectly from contaminated items in the environment. Enteropathogen contamination of the environment is common in CCCs, especially in the infant and toddler area.[5,9]A number of enteric organisms including norovirus, rotavirus, HAV, *G. intestinalis* cysts, *Crytosporidium*oocysts, and *Clostridium difficile*spores can survive on environmental surfaces for extended periods of time. Food contamination may occur when caregivers who change diapers or assist with toileting procedures also prepare food after neglecting effective hand hygiene practices.

A recent review of 75 enteric outbreaks in CCCs implicated bacterial agents (primarily *E. coli*O157:H7) as the cause in 47 percent of cases.[7]Person-to-person transmission accounted for 43 percent of these bacterial outbreaks, 29 percent were associated with food practices, and 11 percent occurred through contact with infected animals. Forty-seven percent of the enteric outbreaks had a viral etiology; the mode of transmission was largely unknown (51 percent) but, when identified, person-to-person transmission (40 percent) was the most common. Parasites accounted for seven percent of the outbreaks; transmission was primarily person-to-person (60 percent).

Viral agents were identified as the primary etiology in 55 percent of outbreaks of acute gastroenteritis in North Carolina CCCs in a 2009 prospective study of 29 outbreaks. Widespread viral contamination of the environment was evident in more than one-half of the affected CCCs.[8]

Effective strategies to prevent fecal-oral transmission in CCCs includes:

- Promoting meticulous hand hygiene among staff and children in association with monitoring hand hygiene practices
- Improved general environmental cleaning and disinfecting, especially in diaper-changing areas
- Ensuring safe food handling practices
- Implementing a surveillance system to identify ill children
- Management of symptomatic children by exclusion, medical treatment, fecal screening, and cohorting of convalescing children
- Prompt notification of health department if an outbreak is suspected

- Communication of relevant information concerning enteric pathogens, symptoms of illness, and infection prevention practices to parents[7]

RESPIRATORY TRACT DISEASES

Respiratory tract infections (RTIs) are a major cause of illness among children attending CCCs. Fairchok et al. estimated the mean annual incidence of 4.2 RTI/child among children attending day care; children had RTI symptoms 11 percent of the time during the 26-month study period.[10] Respiratory organisms prevalent in CCCs include adenovirus, influenza, rhinovirus, and respiratory syncytial virus.[5]

Modes of transmission of respiratory tract viruses include aerosols, respiratory droplets, and direct hand contact with contaminated secretions and fomites. Julian et al. demonstrated that symptomatic respiratory illness was positively associated with microbial contamination (measured using *Enterococcus* spp.) on hands and fomites in CCCs. They concluded that hand contamination is a risk factor for onset of respiratory illness.[9] Very high airborne levels of bacteria were observed in a 2013 study among 16 CCCs. The prevailing component of bacterial aerosol was Gram-positive cocci; airborne *Haemophilus influenzae* strains were found in 25 percent of the investigated rooms.[11]

Strategies to reduce the incidence of acute respiratory diseases among children in CCC include initial and ongoing staff training, enhanced surveillance, increased handwashing by staff and children, practicing respiratory etiquette, and adherence to environmental sanitation.

BLOODBORNE VIRUS INFECTIONS

The risk of contact with bloodborne viruses such as Hepatitis B virus (HBV), human immunodeficiency virus (HIV), or Hepatitis C virus (HCV) in a child care setting is minimal.[5] In general, children and staff members infected with bloodborne pathogens are not excluded from CCCs, and there is no recommendation to screen for these diseases. If cases are discovered in CCC children or staff members, there should be clear guidelines on reporting and working with the local health department to prevent both spread of the disease and potential panic among parents and staff.

To prevent transmission of bloodborne pathogens in CCCs, Standard Precautions should be followed for handling all blood spills and for contact with blood-containing body fluids and wound exudates of all children.

OTHER CONDITIONS

Parvovirus B19: No isolation or exclusion of immunocompetent children or caregivers with parvovirus B19 is necessary.

Varicella-zoster virus: Varicella occurs infrequently in CCCs since the introduction of the varicella vaccine. Children with varicella may return to the CCC after all lesions are dry and crusted, which usually occurs about the sixth day after the onset of rash. All employees and parents should be notified when a case of varicella occurs. Immunocompetent individuals with herpes zoster (shingles) infection do not require exclusion from CCCs if the lesions can be covered.

Herpes simplex virus: Children with active oral lesions caused by herpes simplex virus should be excluded if they cannot control their oral secretions (drooling). The importance of hand hygiene and use of Standard Precautions should be emphasized with caregivers.

Cytomegalovirus: Children with cytomegalovirus infection are not restricted from attendance. Female staff of childbearing age should be counseled regarding risk and optimal methods of prevention.

General Practices

ANIMALS

Animals in day care settings should be clean and free of intestinal parasites, fleas, ticks, mites, and other vermin. To ensure that animals are healthy, they should receive appropriate veterinary care, a certificate of veterinary inspection, or proof of rabies vaccination according to local or state requirements. Children should not handle reptiles, rodents, amphibians, baby poultry, or their habitats. Hands must be washed after handling all animals and animal waste.

ATTENDANCE EXCLUSIONS AND RESTRICTIONS

Daily health checks should be performed upon arrival of each child daily to assess for the presence of illness. Most illnesses do not require exclusion. Children should be excluded from CCC if any of the following conditions are present:

- Illness prevents the child from participating comfortably in activities
- Illness results in a need for care that is greater than the staff can provide without compromising the health and safety of other children
- Illness poses a risk of spread of harmful diseases to others

CCCs should have disease-specific policies, based on state licensing requirements, the Red Book,[5] or National Health and Safety Performance Standards; Guidelines for Early Care and Education Programs[12] for when and how long children must be excluded from care. CCCs also should have age- and symptom-based dismissal guidelines for when a parent is to be called if a child becomes ill while at the CCC and any special restrictions the child needs to be under until the parent arrives (e.g., a separate room).

CLEANERS, DISINFECTANTS, AND SANITIZERS

The U.S Environmental Protection Agency (EPA) recommends that only EPA-registered products be used. Directions for cleaning and sanitizing agents must be easily available and must include how to dilute and mix, a label with expiration date (when applicable), name of product, and health or environmental hazards. State requirements may dictate which products are acceptable. Posting instructions for cleaning and sanitizing each item may be helpful (e.g., in table format). CCC workers must wear gloves when mixing and using disinfectants; face protection should be available if splashing is likely to occur. Surfaces that come in contact with food such as food preparation counters, tables, and highchair trays must be cleaned (water and soap or detergent) and sanitized before and after each use. The sanitizer must be safe for food contact. Items that come in contact with the mouth (eating utensils, dishes, formula bottles, toys) should be cleaned first with soap or detergent and water, rinsed with clear water, then soaked in an appropriate sanitizer (according to manufacturer's instructions), and air dried. Pacifiers should be cleaned, then placed in a dishwasher or boiled for 1 minute after sanitizing. Items washed in a dishwasher do not require further disinfection. Products must be inaccessible to the children to prevent ingestion.

DIAPERING/TOILETING PROCEDURES

Diaper changing areas should not be located in food preparation areas. They should be conveniently located and washable, with all surfaces (including walls and floors) made of nonporous materials without cracks and crevices. There should be at least one diaper-changing table per infant or toddler group. Diaper-changing tables should not be placed between or shared between classrooms or different groups. The changing surface should be covered with paper liners that extend from the child's shoulders to beyond their feet and are discarded after every use. Diaper-changing procedures should be posted at the changing area. Although there is no specific requirement for child care providers to wear gloves during diaper changing activities, based on Standard Precautions gloves are highly recommended when changing diapers and working with body substances, particularly in a group child care setting. Soiled items should be discarded in a secure, hands-free, plastic-lined container with a lid. Clothes should be worn over diapers. Both the child's and the caregiver's hands must be washed with soap and water after each diaper change. The diaper-changing surface should be cleaned and sanitized after each use. Child-sized toilets, steps, or modified toilet seats allow easier access for children. Potty seats are discouraged in CCCs.[12]

ENVIRONMENT

Policies for cleaning frequency, procedure, and sanitizing agents must be established for food areas, child care areas, sleeping areas, and toileting/diapering areas. The recommended routine schedule for cleaning, sanitizing, and disinfecting surfaces in CCCs can be found in Appendix K of the National Health and Safety Performance Standards; Guidelines for Early Care and Education Programs.[12]

Procedures for cleaning up blood and body fluid spills should be in place as outlined in the National health and safety performance standards, Standard 3.2.3.4 "Prevention of Exposure to Blood and Body Fluids."[12]

FOOD SERVICE

Policies must include the following: sanitizing of the preparation area and dishes, hand hygiene for staff members and children, food and breast milk storage (e.g., labeling, monitoring of refrigerator and freezer temperatures, and length of storage), and sanitary preparation of food and baby formula.[12]Staff members whose primary function is to prepare food should not change diapers. Only pasteurized milk and juice products should be offered.

GOVERNMENT REGULATION

The following regulations must be followed: local and state health department rules for reporting diseases and outbreaks, the Occupational Safety & Health Administration (OSHA) Bloodborne Pathogen Standard,[13]the OSHA Hazard Communication Standard[14]to address the potential hazards of chemicals and appropriate protective measures to employees, and the U.S. Food and Drug Administration food safety code.[15]

HAND HYGIENE

CCCs must have written hand hygiene procedures that must be enforced. Situations or times when staff and children must wash hands should be posted in all areas used for food preparation, diapering, and toileting. Liquid soap, disposable towels, and comfortably warm water (between 60°F and 120°F) is appropriate for hand hygiene in child care settings. Sinks should be adjacent to all diaper-changing and toilet areas. The use of alcohol-based hand sanitizers is an alternative to handwashing with soap and water by children over 24 months of age and adults on hands that are not

visibly soiled and should be limited to areas where there are no sinks. Children should not have independent access to alcohol-based hand sanitizers or use them without supervision, as they are flammable and toxic if ingested. Use of antimicrobial soap is not recommended in CCCs.[12]

Developmentally appropriate education for children on basic hygiene and handwashing should be provided (e.g., age-appropriate games). The Centers for Disease Control and Prevention promotes hand hygiene through creative ideas and provides a variety of health promotion materials and resources that may be used by CCCs.[16]

IMMUNIZATIONS AND TUBERCULOSIS SKIN TESTING

Parents or guardians of all children attending CCCs must provide written documentation of immunizations. Immunization records should demonstrate complete immunization for age according to the recommended childhood immunization schedule (**http://www.cdc.gov/vaccines/schedules/easy-to-read/child.html**). Policies are needed to ensure that all children receive age-appropriate immunizations, including annual influenza vaccine. Policies should include specific circumstances under which exceptions to immunization requirements will be made. State mandates on immunization for children in CCC can be found online (**www.immunize.org/laws**). Depending on local disease occurrence, guidelines for hepatitis A, meningococcal, or other vaccines may be advised. Hepatitis A immunization should be considered mandatory for children in CCCs in communities where routine immunization is recommended.

Children who have not received recommended age-appropriate immunizations should be immunized as soon as possible. Medical and legal counsel should be obtained before permitting unimmunized or inadequately immunized children to attend the CCC. If a vaccine-preventable disease to which children may be susceptible occurs in the CCC, all underimmunized children should be excluded for the duration of the possible exposure or until they have completed their immunizations.

All staff members must also receive age-appropriate immunizations and health care. Caregivers should be immunized against influenza annually and immunized against measles according to the adult immunization schedule (**http://www.cdc.gov/vaccines/schedules/easy-to-read/adult.html**). Evidence of varicella immunity should be documented. Caregivers born after 1980 with a negative or uncertain history of varicella and no history of immunization should be tested for susceptibility, or immunized with two doses of varicella vaccine. All adults should receive a one-time dose of Tdap (tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis). OSHA stipulates that employers must offer employees HBV vaccine if they are likely to come in contact with blood. Caregivers should receive written information about HBV and the HBV vaccine. Tuberculin screening with a tuberculin skin test (TST) or an interferon-gamma release blood assay is recommended for all adults who have contact with children in a CCC.[5]

LAUNDERING

Laundering schedules for soft and stuffed toys, dress-up clothes and hats, and bed or crib linen also must be in place. Bedding used by one child should be stored separately from that used by others. Dress-up clothes, sheets/pillowcases, towels, washcloths, and cloth toys should be washed weekly and when visibly soiled. These items should only be used by one child and cleaned and sanitized before use by another child. Laundering may be provided on-site or may be contracted. Clean and soiled linen must be stored separately.

OUTBREAKS AND INFECTIOUS DISEASE OCCURRENCE

Guidelines are needed for disease frequencies that will be considered an outbreak and the actions to be taken, including when the health department will be notified, what communication will be provided to parents (e.g., letters of notification that their children may have been exposed or posted announcements in the CCC rooms affected), and whether any immunizations or prophylaxis will be advised. The CCC should have the ability to contact the local health department quickly to report outbreaks or notifiable diseases. Parental phone numbers, including after-hours numbers, should be available. As necessary, the CCC must cooperate fully with the health department in notifying staff and parents of the possible exposure and in promptly implementing more stringent control measures. Refer to the local health department for applicable regulations. Because prophylaxis (e.g., for pertussis or meningococcal exposure) needs to be prescribed in a timely manner, the method for rapid dissemination of information should be written into the guidelines. These policies and procedures should protect the confidentiality of the children and families. Records for specific diseases and for symptomatic illnesses (e.g., diarrhea, "cold" or upper respiratory symptoms) should be maintained; the length of time records should be kept and the detail they must contain may vary according to local licensing regulations.

PARENTS

Upon the enrollment of each child, the parent(s) should be given written guidelines on the infection prevention measures of the CCC, attendance restrictions for ill children (specific symptoms and diseases and when the CCC will call the parent to take the child home), overall policy for immunizations, tuberculosis (TB) skin testing policy, and infection prevention measures to practice at home that will help prevent transmission of infection. Parents should also be aware of the need to share information about national notifiable infectious diseases. Parents should receive ongoing education on child development, hygiene, nutrition, and management of minor illnesses.

PERSONAL ITEMS

The CCC should have policies in place for storing and preventing the sharing of personal items such as combs, brushes, toothpaste and toothbrushes, coats, hats, boots, and extra clothes. Solid-sided nonporous "cubbies" should be provided for each child.

RESOURCES

CCCs should have resources and reference materials and should develop written policies and practical procedures in terminology easily understood by the staff. The following areas should be addressed: environmental hygiene (cleaning and sanitizing), personal hygiene policies for staff and children, inclusion and exclusion for children and staff illness, families' responsibility to share information about illness, the need to notify local health authorities of certain communicable illnesses, accurate record keeping and tracking for immunizations, and the need to identify the child's source of routine, comprehensive healthcare.[12] CCCs that store and deliver human milk to infants must have a written policy as well as a quality-improvement program to ensure that product is delivered to the correct infant. The local poison control number should be readily available (e.g., posted in each classroom or on each phone). The National Resource Center for Health and Safety in Child Care and Early Education provides health and safety resources for parents and child care providers, including CCC standards, checklists, tip sheets, and toolkits.[17] Quick reference fact sheets, immunization schedules, ready-to-use sample letters, and forms for parents or referrals are available in *Managing Infectious Diseases in Child Care and Schools: A Quick Reference Guide,* published by the American Academy of Pediatrics.[18]

It is recommended that each CCC utilize a health consultant to assist in the development and implementation of written policies for prevention and control of infectious disease and to provide health

education to children, staff, and parents. The consultant should conduct program observations to assess hazards and noncompliance with practices.[12]

SICK CHILD CARE

The safest option is for children with infections that restrict them from the CCC to be cared for at home. If a CCC cares for contagious children, procedures such as physically separating ill children from well children and cohorting of children and staff must be in place. Staff must receive education on disease transmission and prevention before caring for children with communicable diseases. However, children with airborne-spread diseases, such as measles or TB, are excluded from CCC because of a lack of negative pressure and air handling and must not return until medically cleared by a physician.

STAFF

Orientation and training in infection prevention must include the following:

- Hand hygiene techniques
- Respiratory etiquette or hygiene
- Recognition of and reporting of infection
- Exclusion and readmission procedures and policies
- Cleaning, sanitation, and disinfection procedures and policies
- Infection prevention strategies and procedures for diapering, food handling, and special procedures for any staff or children who are at higher risk of infection
- Training on OSHA regulations for Bloodborne Pathogens Standard12 and
- Training on chemical safety for mixing, labeling, and using cleaners and disinfectants
- Immunizations, TB skin testing, and record keeping for training as required by state licensing agency

Work restriction policies for ill staff should be established. The director or the management of the CCC should take responsibility for enforcement.

TOYS

Toys that cannot be washed and sanitized (by hand or in washing machine or dishwasher) should be not used. Mouthed toys or toys contaminated with secretions/excretions should be washed with water and detergent, rinsed, sanitized, and air-dried before reuse. Cloth toys should be machine washable and should only be used by one child before being laundered. Indoor toys should not be shared between groups of infants or toddlers unless they are washed and sanitized before being moved from one group of children to another. Small hard-surface toys can be cleaned in a dishpan with soapy water labeled "soiled toys," or a dry container can be used to bring the soiled toys to the toy cleaning area later in the day. Hard-surface toys can be cleaned and sanitized in the dishwasher. Toys that are not contaminated with body fluids should be cleaned weekly.

WATER AND SAND PLAY

Instructions for cleaning water and sand tables should be in place. Wading and swimming pools, which are highly regulated, are not common in CCCs; when provided, regulations for disinfectant levels and monitoring must be followed.

Conclusions

The impact of CCC-related infectious diseases is substantial, not only on the children, but on caretakers, parents and families, and the community at large. It is vital that CCCs are supported in their efforts to prevent and control the transmission of infectious diseases within their facility. The collaborative efforts of public health officials, licensing agencies, caregivers, physicians, nurses, parents, employers, and other community members are required to adequately address the issues of infection control in CCCs and implement strategies to reduce the incidence of infectious diseases among children.

Future Trends

Increases in the number of working mothers, changes to the family structure, and the desire to provide educational opportunities for young children will continue to drive up the demand for child care.

The development of new pediatric vaccines or changes to the recommended immunization schedule will impact CCCs and have an epidemiological effect on the incidence of infectious disease among children.

Antimicrobial resistance has risen dramatically over the last decade. Antibiotic therapy trends (e.g., recommendations for treating otitis media without antibiotics) may affect the development of antibiotic-resistant organisms. Targeted efforts to educate parents and child care workers regarding judicious antibiotic use in young children attending CCC will become increasingly important.

Antimicrobial surfaces are being used to reduce the survival of microorganisms in healthcare and the food industry. Materials possessing physical properties that can reduce microbial attachment (such as copper) have been developed and used with some success for a number of applications. The use of antimicrobial surfaces in day care may be a promising additional tool alongside with other hygienic measures to reduce the number and severity of CCC-related infectious diseases. Other new technology and practices to improve environmental disinfection in CCCs include improved hydrogen peroxide and "no-touch" disinfection with ultraviolet light or hydrogen peroxide systems.

Emergencies such as natural disasters or terrorist attacks that disrupt power or water or affect the ability of parents to pick up children from the center may impact infection prevention activities in child care. Each CCC should prepare a multihazard written evacuation and relocation plan. Emerging infections, such as severe acute respiratory syndrome or pandemic influenza may also significantly affect child day care centers. CCCs should collaborate with a child health consultant to develop written plans and procedures to address these emergency or disaster situations.

Current developments in health reform and the use of electronic medical records provide an opportunity to initiate surveillance of infectious diseases among sentinel sites such as CCCs in the United States. The Netherlands is the first country to initiate a national surveillance system for infectious diseases in CCCs (the KIzSS network).[19]The aim of the KIzSS network is to acquire a long-term insight into the syndromic and microbiological aspects of CCC-related infectious diseases and to model these aspects with the CCC–setting characteristics. Databases will provide information on the burden of infectious diseases among children and staff in CCCs and will support the development of evidence-based and pragmatic guidelines for infectious disease control in CCCs worldwide. Day care-based sentinel surveillance networks for infectious disease may be forthcoming in other countries.

International Perspective

Annually, thousands of children from other countries relocate to the United States. Children in immigrant families are the fastest growing segment of the nation's children population.[20] Furthermore, international adoptions have been increasing; families in the United States adopt more children from abroad than do families in any other country. Asian and East European countries are the major sources of children adopted through international procedures. Exposure to infectious disease is common in resource-poor settings, and infectious conditions of concern include HBV, HCV, HIV, TB, presence of intestinal parasites, and skin conditions (especially scabies), as well as vaccine-preventable diseases. Therefore, awareness must be high to look for unusual infectious etiologies in CCCs that care for international children. Admission criteria should be well established for all potential clients.

Supplemental Resources

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Dental Services

Author(s): John A. Molinari, PhD
Director of Infection Control

The Dental Advisor
Ann Arbor, MI

Colonel, USAF, DC (ret.)

Dental Infection Prevention and Control Consultant
Northville, MI

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Abstract

This chapter discusses current infection prevention and control measures and safety practices and their implications for the practice of dentistry. Dental healthcare personnel are required to use infection prevention and control measures during patient care to reduce potential risks of disease transmission to patients and themselves. Mandated standards and recommendations from public health agencies call for reduction of potential risks to prevent occupational exposures and adverse patient outcomes through a series of practice controls.

Background

Routine application of effective infection prevention and control strategies continues to require a major commitment by medical and dental care providers, along with their willingness to respond to documented and emerging biomedical and clinical scientifically based information. Governmental regulations from federal agencies such as the Occupational Safety and Health Administration (OSHA) and state and local health departments require dental healthcare personnel (DHCP) to be trained in appropriate infection prevention and control practices and other safety precautions and the application of these measures during patient care to reduce potential risks of disease transmission to patients and themselves. Mandated standards and recommendations from public health agencies such as the Centers for Disease Control and Prevention (CDC) also call for the reduction of potential risks from occupational exposures through a series of other infection prevention and control practices.[1,2,3,4]

Key Terms And Definitions

*Barrier material:*material that prevents the penetration of microorganisms, particulates, and fluids.

*Biofilm:*microbial communities that are characterized by cells attached to a substrate or to each other, are embedded in a matrix of extracellular polymeric substances (glycocalyx), and exhibit increased resistance to dislodgment and the effects of antimicrobial agents.

*Biological indicator:*a device to monitor the sterilization process that consists of a standardized, viable population of microorganisms (usually bacterial spores) known to be resistant to the mode of sterilization being monitored. Biological indicators are intended to show whether the conditions were adequate to achieve sterilization.

*Chemical indicator:*a material containing a chemical that changes color or form with exposure to heat, steam, or ethylene oxide; used to monitor exposure of items to heat-sterilizing or gas-sterilizing agents.

*Dental dam (rubber dam):*a device used to gain operative field isolation that may prevent microbial transmission from patients to DHCP. It also improves visualization, protects the patient, and improves the quality of operative dentistry procedures.

*Dental unit water lines:*small-bore tubing, usually plastic, used to deliver dental treatment water through a dental unit.

*Engineering controls:*controls that isolate or remove a hazard from the workplace (e.g., sharps disposal containers, self-sheathing needles, safer medical devices such as sharps with engineered sharps injury protections).

*Event-related packaging:*a storage practice that recognizes that a package and its contents should remain sterile until some event causes the item(s) to become contaminated.

*Medical waste (regulated):*waste sufficiently capable of causing infection during handling and disposal (e.g., blood-soaked or saliva-soaked cotton rolls, extracted teeth, sharp items such as needles and endodontic files, and surgically removed hard and soft tissues) to merit special handling and disposal.

*Physical (mechanical) indicator:*automated devices (e.g., graphs, gauges, printouts) that monitor the sterilization process.

*Preprocedural mouth rinse:*a mouth rinse used before a dental procedure to reduce the number of microorganisms in the oral cavity.

*Reprocessing (of medical or dental instruments):*the procedures or steps taken to make a medical or dental instrument safe for use on the next patient. Reprocessing encompasses cleaning and the final or terminal step (i.e., sterilization or disinfection), which is determined by the intended use of the instrument.

*Single-use (disposable) device:*a device intended to be used on one patient then discarded appropriately. These items are not intended to be reprocessed (cleaned, disinfected, or sterilized) and used on another patient.

*Spatter:*visible drops of liquid or body fluid that are expelled forcibly into the air and settle out quickly, as distinguished from particles of an aerosol, which may remain airborne indefinitely.

*Work practice controls:*controls that reduce the likelihood of exposure by altering the manner in which a task is performed (e.g., recapping of needles using a "scoop technique" instead of two hands).

Dental Infection Prevention And Control

STANDARD PRECAUTIONS

Standard Precautions apply to contact with blood; all body fluids, secretions, and excretions (except sweat), regardless of whether they contain blood; nonintact skin; and mucous membranes.[5]Standard Precautions should be used in the care of all patients, regardless of their infection status. A second tier of precautions (i.e., Transmission-based Precautions) is designed only for the care of specified patients. There are three types of Transmission-based Precautions: Airborne, Droplet, and Contact Precautions. These additional precautions beyond Standard Precautions are needed sometimes in the dental setting to interrupt transmission of some highly transmissible or epidemiologically important pathogens (e.g., tuberculosis, influenza, and varicella).[5]

In 2007 the CDC published updated isolation guidelines,[5]adding several new elements to Standard Precautions that focus on protection of patients: respiratory hygiene/cough etiquette and safe injection practices.[5]Respiratory hygiene and cough etiquette are a combination of measures designed to minimize the transmission of respiratory pathogens via droplet or airborne routes such as turning the head away from others and maintaining spatial separation—ideally more than 3 feet—when coughing. Additionally, hand hygiene is critical in minimizing the transmission of respiratory illnesses. These measures are targeted to all patients with symptoms of respiratory infection and their accompanying family members or friends beginning at the point of their initial encounter with a healthcare setting (e.g., reception/front desk, ambulatory clinics, dental offices).[5, 6]

The recent increased attention on aseptic technique when handling parenteral medications was a result of the findings of various investigations following outbreaks and transmissions of Hepatitis B virus (HBV) and Hepatitis C virus (HCV). The conclusions of the investigations revealed that reuse of syringes or use of single-dose medication vials or bags of saline solutions for multiple patients was the cause and that these transmissions could have been prevented by adherence to basic principles of aseptic technique for the preparation and administration of parenteral medications.[5,7]Safe handling of parenteral medications, including dental local anesthetics, and fluid infusion systems, is required to prevent healthcare-associated infections (HAIs) among patients, and these recommendations were included in the Special Considerations section of the *Guidelines for Infection Control in Dental Health-Care Settings, 2003*[4]:

1. Do not administer medication from a syringe to multiple patients, even if the needle on the syringe is changed.
2. Use single-dose vials for parenteral medications when possible.
3. Do not combine the leftover contents of single-use vials for later use.
4. If multidose vials are used, cleanse the access diaphragm with 70 percent alcohol before inserting a device into the vial, use a sterile device to access a multiple-dose vial, and avoid touching the access diaphragm. Both the needle and syringe used to access the multidose vial should be sterile. Do not reuse a syringe even if the needle is changed.

5. Keep multidose vials away from the immediate patient treatment area to prevent inadvertent contamination by spray or spatter.
6. Discard the multidose vial if sterility is compromised.
7. Use fluid infusion and administration sets (i.e., intravenous [IV] bags, tubing, and connections) for one patient only and dispose them appropriately.

For further information, see **28. Standard Precautions**.

INFECTION RISKS IN DENTAL CARE SETTINGS

DHCP and patients can be exposed to a wide variety of microorganisms via blood and other oral/respiratory secretions. Multiple potential sources for microbial cross-contamination and infection exist during treatment and instrument reprocessing, including blood; saliva; nasal discharge; hands; instruments; aerosolized spatter from water lines, ultrasonic scaler units, and the patient's mouth; and other contaminated used items.

DHCP routinely work in an environment where the potential exists for percutaneous sharps exposure via handling of numerous dental instruments. Often, DHCP work with syringe needles and sharp instruments without direct visualization of the treatment field. Recognizing the potential for microbial cross-transmission is essential before applying appropriate infection prevention and control precautions during the provision of dental care.

Routes of microbial transmission in clinical settings can be approached in two different, yet compatible, ways. The first approach describes three general routes of transmission, as follows:

1. Direct contact with a lesion, organisms, or potentially infectious secretions when performing intraoral procedures. The earlier practice of treating patients without wearing gloves is an example.
2. Indirect contact via contaminated instruments, equipment, or disposable items. Accidental percutaneous exposures from used needles or other sharps are placed in this category and remain a concern for DHCP and advisory agencies.
3. Aerosolization of microorganisms from patients' blood or saliva while using devices that can generate droplet spatter. Exposure to aerosols created by equipment such as dental handpieces, air-water devices, and ultrasonic scaling devices can lead to a variety of mild-to-severe respiratory infections, including influenza and bacterial pneumonia.[8,9]

A second approach to exposure designation describes similar information, while using DHCP and patients as modes of microbial and disease transmission during patient care, as follows:

1. Patient-to-DHCP passage of potentially infectious microbes. This transmission can occur through breaks in the skin, from accidental sharps exposure, or through exposed mucous membranes (from airborne microorganisms in sprays or spatter particles).
2. DHCP-to-patient exposure to potentially infectious microbes. This transmission represents a microbial challenge as a result of accidental bleeding into a patient's mouth after an accidental sharps exposure or through respiratory droplets passed from DHCP to the patient.
3. Patient-to-patient transmission of infectious microorganisms. This kind of transmission has a much lower chance of occurring, though it has been noted, primarily in medicine, from the use of improperly reprocessed instruments or improper hand washing or glove wearing by healthcare personnel (HCP).

4. Dental practice-to-community transmission of infectious microorganisms. This form of transmission may take place as a result of improper waste management or improper decontamination of dental impressions and appliances.[10]

The most common risks of exposure are those from patient to DHCP. Minimizing the potential for this mode of transmission is a primary focus for a comprehensive infection prevention and control program. The potential for risk of microbial transmission can vary, depending on the number of microbial pathogens present during exposure, host susceptibility to infection, and pathway of exposure (see Table 53-1).[8] It is necessary to understand the nuances of these different transmission modes to be able to implement appropriate infection prevention and control measures.

Table 53-1 Representative Infectious Diseases Encountered in Dentistry

Condition	Habitat	Route
Respiratory Diseases		
Common cold	Upper respiratory tract	Aerosols, contact
Sinusitis	Upper respiratory tract	Aerosols, droplet
Pharyngitis	Upper respiratory tract	Aerosols, droplet
Pneumonia	Respiratory tract	Aerosols, droplet
Tuberculosis	Respiratory, oral	Aerosols, droplet
Childhood Diseases		
Chickenpox	Oral, skin	Droplet, contact
Herpangina	Oral, oropharynx	Droplet, contact
Hand-foot-and-mouth disease	Oral, hands, feet	Droplet, ingestion, contact
Rubella and rubeola	Respiratory tract, oral, skin	Droplet, contact with saliva/blood/exudate
Mumps	Parotids, pancreas, testis, CNS	Droplet, contact with saliva
Cytomegalovirus infection	Salivary glands	Droplet, contact with saliva and blood
Sexually Transmitted Diseases		
Herpetic infections	Oral, pharynx, genitals, skin, viscera	Contact with lesion, saliva, blood, other body fluids
Acute herpetic gingivostomatitis	Oral, gingiva, pharynx	Contact with lesion, saliva, blood, other body fluids
Herpetic whitlow	Fingers, hands	Contact with oral lesion, saliva, exudate, blood
Gonococcal infections	Oral, pharynx	Contact with blood, lesion exudate, nasopharyngeal secretions
Chlamydial infections	Genitals, eyes, oropharynx	Contact with lesion exudate, genital secretions, secretions from eyes

Trichomonal infections	Genitals, oropharynx, oral, gastrointestinal	Contact with mucosa, lesion exudate, saliva, body fluids, blood
Condyloma acuminatum	Anogenital skin, oral, other mucosal areas	Contact with lesion, mucosa, blood, autoinoculation
Syphilis	Genitals, skin, oral mucosa, oropharynx	Contact with mucosa, blood, body fluids, congenital
Infectious mononucleosis	Skin, oral mucosa, genitals, parotids, saliva	Contact with mucosa, saliva, lesion exudate
Hepatitis A	Liver, gastrointestinal	Ingestion, rarely by blood
Hepatitis B	Liver, blood, body fluids	Contact with blood, saliva, body fluids
Hepatitis C	Liver, blood	Contact with blood
Hepatitis D	Liver, blood	Contact with blood
Hepatitis G	Liver	Possible contact with blood
HIV infection	Blood, oral cavity, mucosa, skin	Contact with blood, semen, nonintact skin
CNS, central nervous system; HIV, human immunodeficiency virus.		

Recognition of infection prevention and control challenges should lead to the consideration and application of a few general guidelines regarding Standard Precautions for patient care, as follows:

1. Reduce the concentration of pathogens so that normal host resistance mechanisms can prevent infections.
2. Break the cycle of infection by reducing cross-contamination as much as possible.
3. Treat every patient and instrument as potentially infectious with a life-threatening bloodborne disease.
4. Protect patients and personnel from occupational exposure and possible infection.[3,9]

ASEPTIC PROCEDURES

Asepsis is a fundamental principle relevant to all aspects of infection prevention and control practices. "Aseptic technique" refers to the use of procedures that break the cycle of infection and ideally eliminate cross-contamination. At the heart of all applications of this principle is the requirement for cleaning. Patient care providers are constantly reminded to wash and clean hands routinely before and after patient care, clean instruments before employing sterilization procedures, clean surfaces before applying disinfectants, and clean dental prostheses, such as dentures, before spraying them with or immersing them in chemical agents. Appropriate cleaning reduces the number of contaminating microorganisms, removes organic matter and debris that can interfere with sterilization and disinfection procedures, and assists in keeping work areas clean.[8,9,10,11,12]

For further information, see **30. Aseptic Technique**.

HAND HYGIENE

One component singled out for special mention in the "clean it first" category is hand hygiene. All infection prevention and control recommendations and guidelines stress the importance and clinical

impact of this practice. Hand hygiene is the most important infection prevention and control procedure for minimizing the potential for development of HAIs.[2,4,13] Its primary purpose is the mechanical removal of transient microorganisms from the skin and preventing cross-contamination and cross-infection from contaminated hands.

In addition to traditional hand washing, the CDC also recommends alcohol-based hand products (i.e., preparations containing 60 to 95 percent alcohol) as an option. Extensive research has shown that alcohol-based hand rubs are both highly effective and potentially helpful in improving adherence to hand-hygiene protocols in many healthcare settings. The 2002 CDC hand hygiene guideline states that alcohol-based hand rubs significantly reduce the number of microorganisms on skin, are fast acting, and cause less skin irritation. Alcohol-based hand rubs are available as low-viscosity rinses, gels, and foams for use in healthcare settings.[13]

For further information, see **27. Hand Hygiene**.

Proper hand hygiene and care are commonly overlooked areas for DHCP. With regard to routine, nonsurgical dental procedures, hand hygiene is mandatory before treatment; between patient appointments; after glove removal; before regloving after removing gloves that are cut, torn, or punctured; and before leaving treatment areas.

Surgical hand hygiene can be performed by using either an antimicrobial soap or an alcohol-based hand rub with persistent activity. When an antimicrobial soap is used, the hands and forearms should be scrubbed for the length of time recommended by the product's manufacturer, usually 2 to 6 minutes. When an alcohol-based hand rub with persistent activity is used, the manufacturer's instructions on the amount of product to use should be followed. Hands and forearms should be prewashed with a nonantimicrobial soap and allowed to dry completely before applying the alcohol-based hand rub with persistent activity. After application of the alcohol-based product as recommended, hands and forearms should be allowed to dry thoroughly before sterile gloves are donned.

Although routine hand washing is a fundamental infection prevention practice, it also can be a frequent source of dermatitis or exudative problems, which can have immunologic or nonspecific irritant causes. DHCP who have exudative lesions or weeping dermatitis should refrain from direct patient contact until the condition is resolved.[3] They also can take steps to return damaged skin to epithelial integrity by ceasing to use antiseptics that remove skin oils and replacing them with a nonantiseptic, mechanical cleansing agent, such as liquid soap and water. Another option to decrease the incidence of dermatitis would be to use another method of hand hygiene, such as an alcohol-based hand rub. Studies have indicated that alcohol-based hand rubs are better at killing bacteria and are less damaging to the skin than hand washing with soap and water. They contain emollients that may eliminate the need for lotions and the possibility of using an inappropriate product that will cause glove degradation.

Lotions are often recommended to ease the dryness resulting from frequent hand washing and, more recently, to prevent dermatitis resulting from glove use. Petroleum-based lotion formulations can weaken latex gloves and cause increased permeability. Lotions that contain petroleum or other oil emollients may affect the integrity of gloves and should not be used. At the time of product selection, information should be obtained from the manufacturer regarding interaction between gloves and lotions.[4,13]

Although the relationship between fingernail length and wound infection is unknown, keeping nails short is considered key because the majority of flora on the hands are found under and around the fingernails.[14] DHCP should keep nails short with smooth, filed edges to allow thorough cleaning and

prevent glove tears.[4,13] Hand carriage of Gram-negative organisms has been determined to be greater among wearers of artificial nails than among non-wearers, both before and after hand washing.[15] In addition, artificial fingernails or extenders have been epidemiologically implicated in multiple outbreaks involving fungal and bacterial infections in hospital intensive care units and operating rooms. Therefore, use of artificial fingernails is usually not recommended in dental settings,[4] and CDC does not recommend wearing artificial fingernails or extenders when having direct contact with patients at high risk (e.g., those in intensive care units or operating rooms).[4,13]

PREPROCEDURAL MOUTH RINSING

Preprocedural mouth rinsing refers to the use of an antimicrobial mouth rinse by the patient before a dental procedure. Its objective is to reduce the number of oral microorganisms that may be released from a patient's mouth during dental care in the form of aerosols or spatter that subsequently contaminate equipment, operatory surfaces, and DHCP. Preprocedural mouth rinses should be considered as routine use for all patients.[4,9,16]

To date, no scientific evidence confirms that preprocedural mouth rinsing prevents disease transmission in the dental operatory, but studies have shown that a preprocedural rinse with a product containing an antimicrobial agent (e.g., chlorhexidine gluconate, essential oils, povidone-iodine) can reduce the level of oral microorganisms generated when performing routine dental procedures with rotary instruments (e.g., dental handpieces, ultrasonic scalers), lowering the potential for cross-contamination and cross-infection. Preprocedural mouth rinses may be most beneficial before prophylaxis using a prophylaxis cup or ultrasonic scaler, because a dental dam cannot be used to minimize aerosol and spatter generation and, unless the provider has an assistant, high-volume evacuation is not commonly used.[4,16]

UNIT-DOSE CONCEPT

Unit dosing of supplies and equipment minimizes cross-contamination during dental treatment or dental laboratory procedures. Unit dosing refers to the dispensing of an amount of material that is sufficient to accomplish a particular procedure before patient contact; any excess is discarded at completion. Some waste is involved, but the use of unit-dose materials prevents cross-contamination of such items as cotton products, impression materials, amalgam capsules, composite compules, laboratory pumice, and other items.[9]

PATIENT SCREENING AND EVALUATIONS

Screening and evaluation processes are the first steps in providing appropriate patient care. The goals of patient evaluation and screening are to reduce the potential of serious complications either during or as a result of dental treatment and to identify a previously undiagnosed medical problem or one for which the patient is not receiving appropriate medical care. A thorough head, neck, and oral examination can often identify patients with oral ulcerations, lesions, infections, or neoplasia. It is often the dentist who first notices irregular oral conditions or of whom the patient initially asks about an irritating spot in or around the mouth. Examination may indicate a need for medical referral for the patient (i.e., for diagnosis of active tuberculosis or head and neck cancer).

Obtaining, reviewing, and updating the patient health history at subsequent appointments can alert practitioners to medical problems that, in conjunction with dental treatment, could adversely affect the patient. Essential elements of a medical history that help the clinician include the following[9]:

1. Identify the patient.
2. Establish the chief complaint.
3. Record experiential dental history.
4. Determine the current health status of the patient.
5. Provide a record of major hospitalizations.
6. Record history of childhood and adult illnesses.
7. List medications the patient may be using.
8. Record evidence of allergies.
9. Identify pertinent familial and social histories.
10. Obtain a review of major organ systems.

The medical history does not identify all infectious patients; it should not be used to identify the "infectious disease risk" of a patient. Patients may not know their infectious status or may not be willing to disclose pertinent infection information in their medical history, and many infectious patients do not manifest classic symptoms. Standard Precautions as defined by the CDC must be used in providing patient care in dentistry.[2,4,5,17,18]

The medical history can alert DHCP to patient problems and complaints resulting from previous dental office visits. Hypersensitivity reactions to latex-containing products (e.g., latex gloves, latex dental dam, latex prophylaxis cups) or hypersensitivity or other adverse reactions to dental medicaments or restorative materials may be identified. Also, the patient's medical history may identify trauma from local anesthetic injection or treatment or the inability of individuals with dependency issues relating to alcohol to use mouth rinses containing alcohol.

EMPLOYEE HEALTH

Vaccine Recommendations

Immunization of DHCP before they are placed at risk is the most efficient and effective use of vaccines in healthcare settings. The perception that HCP vaccination involves only HBV protection is now outdated. The trend of moving away from widespread dependency and use of antimicrobial chemotherapy has been gaining momentum since the early 1990s, and a new phase of immunization practices to prevent disease already has been initiated to protect at-risk HCP from healthcare-associated transmission of additional vaccine-preventable infections, such as influenza, measles, mumps, rubella, varicella (chicken pox), tetanus, diphtheria, pertussis, and *Streptococcus pneumoniae* pneumonia.[19,20,21]

The HBV vaccine series must be provided free to any nonimmune employee who may have occupational exposure to bloodborne pathogens,[3] including the practitioner, dental assistant, dental hygienist, and laboratory technician; this applies to full-time, part-time, temporary, and probationary employees. Employers must provide the vaccination within 10 working days of initial assignment. New employees can continue to provide patient care during the period required to complete the vaccination series. The employee is sent to a designated medical professional for evaluation. This professional evaluates the employee for contraindications to vaccination, then either vaccinates the employee or discusses the contraindications. The professional sends the employer a written opinion on whether the vaccine is indicated and whether it was received. The employer provides a copy of the written opinion to the employee within 15 days. The time sequence for receipt of the vaccine is 0, 1, and 6 months for the three-injection regimen. A titer or antibody testing is required approximately 2 months after the employee finishes the vaccination series.

Employees may refuse to be vaccinated; if so, they must sign the "Informed Refusal for Hepatitis B Vaccination" form (see Appendix A at the end of the Bloodborne Pathogens Standard).[3,4] Currently, the U.S. Public Health Service guidelines do not recommend booster doses. If a booster is recommended in the future, however, it must be provided at no cost to the employee. Documentation of the HBV vaccination should be placed in the employee's medical record.

Work Restrictions for DHCP

The CDC recommends having comprehensive written policies regarding work restriction and exclusion that include a statement of authority defining who can implement such policies. DHCP are responsible for monitoring their own health status and should be encouraged to report illnesses or exposures.[4,22]

DHCP who have acute or chronic medical conditions that render them susceptible to opportunistic infection should discuss with their personal physicians or other qualified authority whether the condition might affect their ability to safely perform their duties. Decisions concerning work restrictions are based on the mode of transmission and the period of infectivity of the disease.[4,22]

For further information, see **100. Occupational Health**.

POST-EXPOSURE EVALUATION AND FOLLOW-UP

Prevention

Avoiding exposure to blood and other potentially infectious body fluids and protection by immunization are primary strategies for reducing occupationally acquired infections, but occupational exposures still occur.[23] A combination of Standard Precautions and administrative, engineering (e.g., needle recapping devices, sharps containers), and work practice controls (e.g., not recapping needles with a two-handed technique) is the best means of eliminating or minimizing occupational exposures. Written policies and procedures to facilitate the prompt reporting, evaluation, counseling, treatment, and medical follow-up of all occupational exposures should be available to all DHCP.

Many safer versions of sharp devices used in hospital settings have become available, and their impact on reducing injuries has been studied. Aspirating anesthetic syringes that incorporate safety features have been developed for dental cases, but the low injury rates in dentistry limit assessment of their effect on reducing injuries among DHCP.[4] The impact of safer medical devices in other settings suggests that devices with engineered safety features could reduce percutaneous injuries in dental settings, as well. In 2001, OSHA revised its Bloodborne Pathogens Standard, with the revisions clarifying the need for development of a program to prevent sharps injuries that includes a process to identify, evaluate, and select engineering and work practice controls (e.g., evaluating safer dental devices). Under the revised OSHA Bloodborne Pathogens Standard, employees directly responsible for patient care (e.g., dentists, hygienists, and dental assistants) should actively participate in this safety program.[3,24] The CDC has developed sample forms to assist DHCP in screening and evaluating devices for clinical acceptability.[25]

Post-exposure Management

An exposure incident may be defined as a needlestick or any puncture wound with a contaminated object, a splash of blood or body fluid onto mucous membranes, or a splash of blood or body fluids onto nonintact skin. The Bloodborne Pathogens Standard requires that any employee who has

experienced an exposure incident be offered a free, confidential medical evaluation and follow-up immediately.[3]

When an employee has an exposure incident, first aid should be administered as necessary. Wounds should be washed with soap and water, and mucous membranes should be flushed with water. The incident should be reported to the safety and health manager or the employer, who should initiate referral to a qualified professional as soon as possible for medical evaluation. If the source individual (usually the patient) is known and that person gives consent, he or she should be sent to the qualified professional for blood testing. Documents that should accompany the employee include a copy of the Bloodborne Pathogens Standard, the employee's job description, an incident report (see Table 53-2) describing the circumstances, and the employee's HBV vaccine status and other relevant medical information.[4,22,23,26] The qualified professional evaluates the exposure incident, arranges for blood testing of the employee and source individual, notifies the employee of the results of all testing, provides counseling, provides post-exposure prophylaxis if necessary, and evaluates any subsequently reported illnesses.[4,23,27]

Table 53-2 Incident Report Recommendations

Date and time of exposure
Details of the procedure being performed, including where and how the exposure occurred and whether the exposure involved a sharp device, the type and brand of device, and how and when during its handling the exposure occurred
Details of the exposure, including severity and the type and amount of fluid or material. For a percutaneous injury, severity might be measured by the depth of the wound, gauge of the needle, and whether fluid was injected; for a skin or mucous membrane exposure, by the estimated volume of material, duration of contact, and the condition of the skin (e.g., chapped, abraded, or intact)
Details about the exposure source, including whether the source material was known to contain HIV or other bloodborne pathogens and, if the source was infected with HIV, the stage of disease, history of antiretroviral therapy, and viral load, if known
Details about the exposed person (e.g., HBV vaccination and vaccine-response status)
Details about counseling, postexposure management, and follow-up
HBV, Hepatitis B virus; HIV, human immunodeficiency virus. Data from CDC. Updated US Public Health Service guidelines for the management of occupational exposures to HBV, HCV, and HIV and recommendations for postexposure prophylaxis. *MMWR Morb Mortal Recomm Rep*2001 Jun 29; 50(RR-11):1–42 and Cleveland JL, Barker L, Gooch BF, Beltrami EM, Cardo D. NaSH Group: Use of HIV post-exposure prophylaxis by dental health care personnel: an overview and updated recommendations. *J Am Dent Assoc*2002 Dec;134(12):1619–1626.

The qualified professional should send the employer documentation that the employee was informed of the evaluation results and the need for any further follow-up and provide a recommendation as to what medical treatment is advised, such as vaccination or post-exposure prophylaxis, and what was received by the employee. The employer should provide a copy of this written opinion to the employee within 15 days of the completed evaluation. Documentation should also be provided to the employer as to the human immunodeficiency virus (HIV), HBV, or HCV status of the source individual.

To prevent future occupational exposure incidents, the circumstances of the incident need to be evaluated. This evaluation must be documented as required by law (i.e., OSHA) and may be accomplished by including the following information:

1. Type of exposure incident
2. Measures taken to prevent reoccurrence
3. Evaluation of policies

4. Engineering controls
5. Work practices and personal protective equipment (PPE) used at the time of the exposure incident
6. Identification of any other areas with similar patterns of occurrence

For further information, see **101. Occupational Exposure to Bloodborne Pathogens**.

BARRIER TECHNIQUES

Using barriers is important in reducing tissue contact with potentially infectious pathogens and materials and ultimately reducing cross-contamination and cross-infection between DHCP and patients. DHCP must wear protective attire, including disposable gloves, eyewear (e.g., protective eyewear with solid side shields, chin-length shield), and protective clothing, when performing treatment procedures capable of causing splash, spatter, contact with body fluids, contact with mucous membranes, or touching items or surfaces that may be contaminated with these fluids (see Table 53-3). These procedures include the use of high-speed or low-speed handpieces, manipulation with sharp cutting instruments during periodontal and prophylaxis treatments, spraying water and air into a patient's mouth, intraoral surgical procedures, cleanup of the treatment area, and instrument reprocessing. The type of protection should be related to the dental procedure, not the patient's infectiousness.

Table 53-3 Protective Barriers

Facemask
It must fit the face well to minimize open spaces on the side of the face; it should be able to prevent penetration of aerosolized particles generated during the procedure for which the mask is worn; it should not rest against the mouth, as the wearer's breath can condense and wet the fabric[12]
Protective Clothing
The outer occupational garment should be fluid resistant, not fluid proof; appropriate garment material should not permit blood or other potentially infectious fluids to pass through or reach the healthcare personnel's clothes or epithelial/mucosal tissues; for routine dental procedures, cotton or cotton/polyester laboratory coats or clinic jackets with cuffs are satisfactory; protective garments must be changed at least when visibly soiled; protective garments must be removed before leaving the workplace
Protective Eyewear
It should have solid side shields to afford peripheral protection; it must meet the American National Standards Institute Occupational and Educational Eye and Face Protection Standard for impact resistance; it should be able to withstand cleaning and disinfection between patient procedures; it should not distort the operator's vision; a face shield worn with a mask can be worn when greater protection is desired

Disposable materials must be discarded after a single use. Reusable materials must be reprocessed in an acceptable manner (i.e., cleaning followed by sanitization, disinfection, or sterilization) based on the level of contamination and on the inherent properties of the material to withstand the level of reprocessing. If the materials are damaged or become permeable during use, they must be replaced with a fresh item to contain contamination and maintain barrier efficacy. The practitioner should choose either sterile or clean barriers (i.e., gloves) as dictated by the procedures.[2,4,12]

Gloves

Properly fitting gloves protect DHCP from direct exposure through cuts and abrasions, which often can be visually undetected on the hands. Gloves used during the provision of patient care are single-use items and must not be used on another patient or washed for reuse. The American Dental Association (ADA) initially approached the issue of practitioners wearing disposable gloves in an important 1976 publication aimed at protecting DHCP from occupational HBV infection. At that time, the ADA Council of

Dental Therapeutics wrote: "The use of gloves in a practice should be encouraged through dental school training for those procedures in which there is bleeding."[28] The language was strengthened and expanded in later series of ADA and CDC statements and recommendations. In today's DHCP activities, the routine use of disposable gloves constitutes the most important aspect of PPE protection.[4,6,9]

The most common type of glove worn during patient treatment is composed of latex. This material is manufactured in many sizes and specifications (e.g., ambidextrous, right or left hand, low powder, powder-free, low protein), provides a comfortable fit and tactility for most users, and provides an effective barrier during the time interval of most routine procedure appointments. Other types of disposable gloves include medical vinyl, nitrile, and neoprene. The use of sterile latex or other treatment glove materials is indicated when surgical procedures are performed. These gloves are available as right-handed and left-handed fitted items and offer clinicians excellent tactility, comfort, and dexterity.

Puncture-resistant and chemical-resistant reusable utility gloves are a type of nontreatment glove routinely worn when handling and cleaning contaminated instruments, when cleaning up the operatory area, and when performing surface cleaning and disinfection procedures. By necessity for the tasks undertaken, these gloves are puncture resistant, resistant to chemical toxicity, and able to withstand multiple cleaning and disinfection exposures. These utility gloves are usually composed of nitrile or neoprene, and some types can even withstand repeated heat sterilization in an autoclave.

Dental and medical HCP often report occupation-related allergic and nonallergic reactions. Although it was once thought that latex was the most common causative agent, most reactions are not the result of contact with latex-containing products.[29] Data from the ADA indicate a decline in prevalence of type I latex hypersensitivity from 8.5 to 4.3 percent. This might be attributable to the use of latex gloves with lower allergen content.[4,30] Studies have shown that as many as 33 percent of DHCP who underwent allergy testing had occupation-based allergic contact dermatitis (ACD), making it more prevalent than an allergy to natural rubber latex (NRL) protein.[29,31,32,33] Allergic reactions occur as one of two types: type I (immediate or immunoglobulin E) (IgE) and type IV (delayed hypersensitivity or ACD). Many healthcare and personal products contain NRL and can contribute to latex allergic reactions. In addition to latex gloves used in healthcare environments, many other devices can contain latex as a component, including blood pressure cuffs, dental dams, elastic bands on masks, adhesive bandages, vascular catheters, nitrous oxide nose cones, prophylaxis cups, and intubation tubes. Methacrylates, glutaraldehyde, and rubber processing chemicals are also sources of potential allergens or irritants in dentistry.

As with any allergy, avoiding the allergen is key; however, DHCP should not diagnose themselves, use "self-cures," or randomly change brands of gloves or other products. DHCP with a suspected occupation-related allergy should obtain a definitive diagnosis by a qualified healthcare professional to carefully determine its specific etiology and appropriate treatment as well as work restrictions and accommodations.[4,34]

Type I hypersensitivity is the result of a humoral IgE response against certain latex proteins.[35,36,37,38] The clinical reaction usually occurs as a localized urticaria, or cutaneous anaphylaxis, within minutes after a sensitized person comes in contact with latex allergens. Donning latex gloves and placing a rubber dam are common stimuli. The individual rapidly develops this "wheal and flare reaction" by experiencing itching, developing hives, and developing possible local edema. In some instances when these individuals are challenged via the airborne route from aerosolized allergens, more serious

respiratory symptoms can occur, including wheezing, coughing, shortness of breath, and respiratory distress. Perspiration of hands can induce sensitization by leeching out water-soluble protein allergens from the latex glove material. NRL proteins also can adhere to glove powder particles and remain suspended in the air during removal of such items from boxes or during glove donning and removal. The use of nonpowdered, low-allergen gloves by clinicians may decrease the potential risk of airborne exposure to NRL allergens for DHCP and patients.

Type IV hypersensitivity develops from the infiltration of sensitized $CD4^+$lymphocytes and other leukocytes.[36,37]Development of this contact dermatitis is much slower, often occurring 12 to 24 hours postchallenge. The resultant chronic inflammation presents with characteristic epithelial lesions from induration and walling off of affected sites, leading to necrosis, scabbing, and epithelial sloughing within 72 to 96 hours. The specific immune response in this instance is directed against certain water-soluble chemicals added during the manufacturing process, including chemical accelerators, vulcanizers, and antioxidants. Avoiding or reducing exposure to rubber processing chemicals (i.e., thiurams, carbamates) can be a challenge. DHCP allergic to these chemicals should avoid them and use products made of polyvinyl chloride, polyurethane (polyisocyanates), or styrene-based copolymers.[29,39]

Many governmental, manufacturing, and healthcare organization initiatives have been undertaken to protect HCP and their patients from these types of adverse reactions to latex-containing materials.[34,40]

These initiatives include the following:

1. Nitrile, vinyl, neoprene, and other nonlatex gloves may be worn for patient treatment by sensitive DHCP, in addition to using an expanding list of other nonlatex items and materials. For example, many brands of prophylaxis cups and orthodontic elastic bands are now manufactured latex-free.
2. DHCP should be aware of other developing technologies concerning manufacture of nonlatex gloves and be able to devise special precautions for latex-allergic patients (e.g., schedule them as the first patient of the day to minimize exposure to aerosolized latex particles, set up specific treatment areas with minimal presence of items containing latex). U.S. Food and Drug Administration (FDA) regulations in effect as of September 1998 disallowed the use of the misleading term *hypoallergenic*to describe latex gloves and required all NRL-containing medical devices to be labeled as such, including a cautionary statement warning of the potential of NRL to cause allergic reactions.
3. The National Institute for Occupational Health and Safety (NIOSH) recommends that if latex gloves are chosen, the healthcare facility provide personnel with reduced-protein, powder-free gloves.[34]

Masks

DHCP are routinely exposed to high concentrations of aerosols and spatter during various treatment procedures involving the use of a handpiece, ultrasonic scaler, or air/water spray; while grinding items contaminated with oral secretions; or while cleaning contaminated instruments. Airborne microorganisms that can be infectious via this route of exposure include staphylococci, streptococci, tubercle bacilli, herpes viruses, influenza viruses, and gonococci. Routinely using an approved facemask protects DHCP from microbe-laden droplets. Personnel masks are considered medical devices, similar to disposable gloves, and are reviewed by the FDA for approval. The American Society for Testing materials (ASTM) is responsible for medical facemask performance classification, and defines terms used to describe the key features. Masks that filter at least 95 percent of particles 3 to 3.2 μm provide effective protection, with many types now able to filter out 1 μm particles.[41]The mask should be changed between patients and more frequently when exposure to heavy spatter or aerosols or both occurs during treatment or if it

becomes moist or wet.[2,4] This is an important consideration because wet fabric may serve as a vehicle for microbial passage through the mask.

Protective Eyewear

The eyes and other surrounding tissues of DHCP can be exposed to a variety of macroscopic and microscopic particles, which can cause mechanical trauma (e.g., from tooth fragments, amalgam, surgical tissue debris), chemical injury from splashing, or infection (i.e., conjunctivitis caused by staphylococci, gonococci, or herpes simplex viruses). Also, HBV was shown years ago to be infectious in susceptible primates through the conjunctiva. Protective eyewear, such as goggles, glasses with side shields, or face shields, should be used during procedures in which aerosol generation or splash or spatter is anticipated.[2,4,12] DHCP should choose an appropriate device based on the level of protection indicated. A facemask should be used in conjunction with an eye protection device, even if the device is a face shield, to reduce contamination through the nasal and oral portals of bacterial entry.

Protective Clothing

The following portion of the December 6, 1991, federal OSHA Bloodborne Pathogens Standard mandated employers to address employee protective clothing[3]:

Gowns, Aprons, and Other Protective Body Clothing: Appropriate protective clothing such as, but not limited to, gowns, aprons, lab coats, clinic jackets, or similar garments shall be worn in occupational exposure situations. The type and characteristics will depend upon the task and degree of exposure anticipated.

For routine dental procedures, cotton or cotton/polyester laboratory coats or clinic jackets with elastic or stocking net cuffs are satisfactory. The end of the sleeves should be fashioned in such a way so that gloves can be cuffed up over them to protect the forearm. Protective clothing should be changed at least daily and definitely when visibly soiled. Protective clothing must be removed before leaving the workplace.[3,4,9]

Dental Dam

In many restorative and endodontic dental procedures, the routine use of a dental dam (i.e., rubber dam) provides an effective intraoral barrier, affording protection for DHCP and the patient.[42] When the use of a dental dam is indicated in any dental procedure, a high-volume evacuator must be used if splash or spatter is generated. When used in conjunction with each other, the dental dam and high-volume evacuator minimize the potential for spatter during treatment and DHCP contact with the patient's oral mucosa and secretions.

Environmental Barriers

Using disposable environmental barriers offers an alternative to the use of surface cleaning agents and chemical disinfectants for treatment area surfaces that may become contaminated by touch, spatter, or aerosols; nonremovable parts of the dental unit; and containers of supplies/materials that cannot be appropriately cleaned and disinfected. This technique is discussed in more detail in the section on environmental surface and equipment asepsis.

INSTRUMENT REPROCESSING: CLEANING, DISINFECTION, STERILIZATION

A basic principle for effective infection prevention and control is *do not disinfect when you can sterilize*. Sterilization of contaminated reusable instruments **that have been cleaned**is the most important component of an asepsis program. An initial distinction must be made between the antimicrobial outcomes of sterilization and disinfection. As presented earlier, "sterilization" is defined as the destruction of all forms of life, with particular reference to microbial forms. The limiting requirement and basic criterion for accomplishment of sterilization is the destruction of high numbers of bacterial and mycotic spores, the most heat-resistant microbial forms. In contrast, the term "disinfection" refers only to the inhibition or destruction of most organisms; spores are not killed during disinfection procedures.[8,9,10,11,12]

Patient care items and equipment are categorized as critical, semicritical, or noncritical depending on the potential risk for infection associated with their intended use (see Table 53-4).[4,43]Critical items used to penetrate soft tissue or bone have the highest risk of transmitting infection and should be sterilized by heat (see Figure 53-1). Examples include scalers, burs, and needles. Semicritical items touch only mucous membranes or nonintact skin and have a lower risk of transmission, but because most semicritical items in dentistry are heat tolerant, they also should be sterilized using heat. Examples include air/water syringe tips, mirrors, and amalgam condensers/burnishers (see Figure 53-2). Noncritical patient care instruments contact only intact skin, which can serve as an effective barrier to microorganisms. Examples include medical devices such as external components of x-ray heads or blood pressure cuffs that come into contact only with intact skin. These items require cleaning and, if visibly contaminated, disinfection between patient appointments.

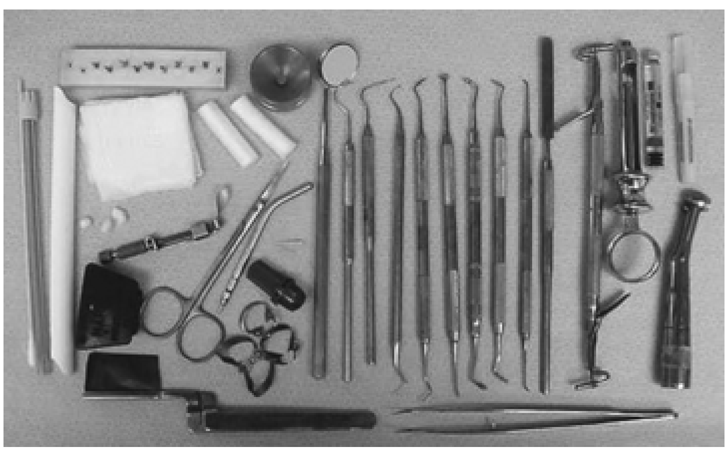

Figure 53-1.

Representative dental instruments that require heat sterilization between patient uses and other disposable supplies that are single-use items.

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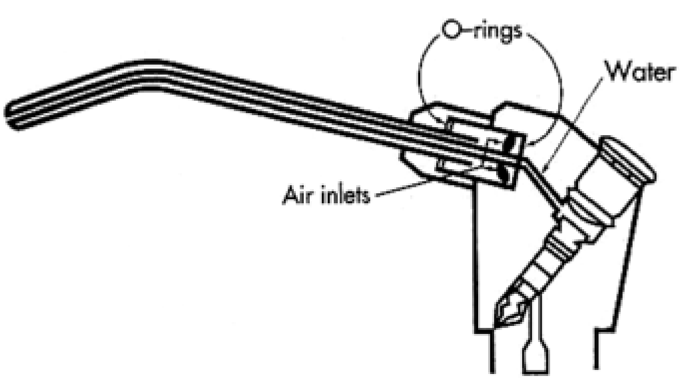

Figure 53-2.

Cutaway representation of a dental air-water syringe.

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Table 53-4 Modified CDC/Spaulding Classification of Contaminated Patient Care Items and Environmental Surfaces

Classification	Description	Dental Clinic/Laboratory Examples
Patient Care Items		
Critical	Penetrates tissue; contacts open tissue	Cutting instruments; surgical burs, files, and needles; handpieces and scaler tips

Semicritical	Contacts mucosa	Hand instruments (noncutting); mouth props; plastic prophy angles; rubber dam frames
Noncritical (no intraoral contact)	Contacts unbroken skin	Blood pressure cuffs; radiograph headcone; pulse oximeters
Environmental Surfaces		
Clinical contact	Usually contacts dental personnel, but not patients	Dental unit surfaces; laboratory equipment; radiology equipment
Housekeeping	Rarely contacts dental personnel or patients	Floors; walls; countertops

* To be used only on items that are destroyed by heat.
†Some examples include iodophors, combination synthetic phenolics, bromides, and sodium hypochlorite.
HBV, Hepatitis B virus; HIV, human immunodeficiency virus.

Several dental devices that touch mucous membranes are attached to the air and water lines of the dental unit. Among these devices are high-speed and low-speed handpieces, prophylaxis angles, ultrasonic and sonic scaling tips, air abrasion devices, and air/water syringe tips. Internal surfaces of dental handpieces and other devices connected to the air and water lines of the dental unit can become contaminated with patient material during use (see Figure 53-3). This retained material may contain microbial contamination, which may be expelled intraorally during subsequent use. Physical design of the equipment and restricted access to many internal surfaces limit effectiveness of cleaning and disinfection with chemical germicides. Dental handpieces and other devices connected to air and water lines must be cleaned and heat sterilized the same as any other heat-stable instrument. The standard of care in this area has evolved to the level where all reusable heat-stable instruments—high-speed handpieces; low-speed handpieces; ultrasonic tips; reusable prophylaxis angles; and other contaminated items that come in contact with patients' blood, saliva, or mucous membranes—must be sterilized in an FDA 510K-cleared heat sterilizer before use.[2,4,44,45,46]

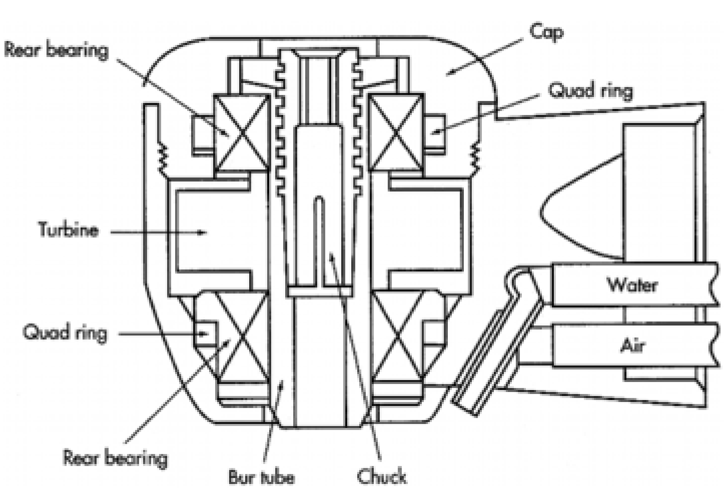

Figure 53-3.

Cross-section of high-speed dental handpiece turbine and air-water lines.

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The use of heat has long been recognized as the most efficient, reliable method of sterilization. Several methods of heat sterilization are available and effective in dental healthcare settings, including steam under pressure (autoclave), dry heat, or unsaturated chemical vapor units. Major advantages and disadvantages of these sterilization modalities are presented in Table 53-5.

Table 53-5 Advantages and Disadvantages of Major Methods of Heat Sterilization

Method	Advantages	Disadvantages

Steam autoclave	Rapid turnaround time, low cost per cycle, no toxic/hazardous chemicals	May corrode instruments, cannot be used with many plastics
Dry heat oven	Does not corrode instruments, no toxic/hazardous chemicals, low cost per cycle	Long cycle time, cannot be used with plastics, paper products may char
Rapid heat transfer	Short cycle, items are dry after cycle	Cannot sterilize liquids, may damage plastic and rubber items, door cannot be opened before end of cycle, small capacity per cost, unwrapped items quickly contaminated after cycle
Unsaturated chemical vapor	Good turnaround time, less corrosive to instruments	Uses toxic/hazardous chemicals, requires fume ventilation, cannot be used with many plastics

Note: Time and temperature parameters may vary by manufacturer. Follow manufacturer's instructions for the particular unit. To avoid contamination, packages should be allowed to dry in the sterilizer before they are handled.
From Miller CH. Sterilization and disinfection: what every dentist needs to know. *J Am Dent Assoc*1992;123:46–54.

Of all methods available for sterilization, steam sterilization, which is dependable and economical, is the most widely used for wrapped and unwrapped critical and semicritical items that are not sensitive to heat and moisture.[10]Ethylene oxide (ETO) gas sterilization also is useful in limited circumstances in large facilities for heat-labile reusable items.[9,11]However, dental handpieces cannot be effectively sterilized with this method because of decreased penetration of ETO gas flow through a small lumen.[4]

Although a practitioner may prefer one type of heat sterilizer over another, no single method of sterilization may be suitable for the range of items used in dental care; the manufacturer's instructions should be consulted. The ongoing data collection by the Environmental Protection Agency (EPA), FDA, and OSHA led to development of increasingly stringent standards for EO emissions, residue limits, and allowable exposure limits for workplace personnel.

The historical practice of using liquid chemical sterilants in dentistry (i.e., "cold sterilization"), including agents such as glutaraldehyde or chlorine dioxide, is no longer necessary or appropriate because most reusable instruments and devices used in dentistry can withstand sterilization by one of the above-mentioned common processes.[9]If certain devices are not sterilizable, single-use disposable items should be considered.

The goal of instrument reprocessing is to deliver sterile instruments to patients. When cleaning and reprocessing contaminated instruments between patient treatment procedures, the instrument recirculation system should be logical and organized in such a manner as to (1) accomplish reprocessing and sterilization most efficiently and (2) minimize procedures that can place employees at risk for percutaneous or sharps exposures or other hazards. Instrument reprocessing should not occur in the treatment operatory. The design of the instrument reprocessing area should include separation of a contaminated item section from the clean/sterile item section. An instrument reprocessing area may be

divided into several subsections or areas: receiving, cleaning, packaging, sterilization, storage, and dispensing.[4,9,11] Many choices for implementation are available for practitioners, each of which can be effective when used appropriately.

For further information, see **31. Cleaning, Disinfection, and Sterilization**.

Receiving Area

Procedure trays should be kept covered during transport from the operatory. Instruments and other contaminated materials arrive at the receiving area and undergo early preparation, such as immersion in a holding solution and disposal of waste, with DHCP wearing heavy-duty utility gloves and other PPE as indicated (e.g., protective eyewear, facemask, protective apparel). The initial use of a holding solution (usually a detergent or enzymatic cleaner in water) is not a requirement, but it may be useful in keeping bioburden moist when instrument cleaning cannot occur for extended intervals. If a holding solution is used, care must be taken when transferring contaminated instruments to the next step, the cleaning process, to prevent sharps injuries.

Cleaning Area

Precleaning of contaminated instruments is the most important preparatory stepbecause bioburden can act as a barrier to subsequent sterilization. Instruments are placed in an ultrasonic cleaner or instrument washer for the prescribed period then inspected visually for any residual bioburden. The residual bioburden may be removed by an additional cycle of cleaning or by carefully scrubbing while immersed (i.e., under the surface of cleaning solution) to minimize splash using an appropriate long-handled brush and then rinsed. Ultrasonic cleaning units or other mechanical cleaning devices are more efficient and safer than hand scrubbing. Hand scrubbing should be avoided as much as possible because of potential for injury.

Packaging Area

In the packaging area, sufficient counter space is needed to accomplish several different procedures to prepare instruments for sterilization. These procedures include inspection and arranging of instruments (e.g., in open position) for packaging, organization of supplies into unit doses, and grouping of dried instruments into appropriate cassettes, pouches, bags, or wraps suitable for heat sterilization methods. Instrument cassettes minimize manual handling of contaminated items and decrease the potential for accidental sharps exposure.

Sterilization Area

The sterilization area needs sufficient space for sterilizers, as required by the size of the practice and the number of treatment operatories, and appropriate ventilation to exhaust fumes and sterilizer odors. Additional space is necessary to allow cassettes, trays, and packages to cool after removal from sterilizers.

Storage and Dispensing Area

The storage area calls for sufficiently closed or covered storage space for sterilized packages. The goal is to maintain sterility until the package integrity is broken at the time of use. Packaged instruments and other items must be stored in a manner that prevents contamination. Dental supplies and instruments should not be stored under sinks or in other locations where they can become wet, soiled, or damaged. Instruments should not be stored unpackaged. Although some facilities place an expiration date (i.e., date-related shelf life) on every sterilized package, many facilities have switched to event-related

practice. This latter approach recognizes that the product should remain sterile indefinitely unless some event causes it to become contaminated (e.g., torn or wet packaging).[4,47] If packaging is compromised, the instruments must be repackaged in new wrap and resterilized. An organized location for preparation of instrument setups and their distribution to operatories brings all of the other steps together before provision of patient care.

Sterilization Monitoring

The application of effective quality control measures is essential in the overall area of instrument reprocessing. How do we know that the most important piece of infection prevention and control equipment is functioning properly? There are numerous equipment malfunctions and human factors that can adversely affect a sterilizer's performance. It is imperative that sterilizer effectiveness be routinely monitored and verified using physical (mechanical), chemical, and biological indicators (BIs). Physical (mechanical) monitoring of each sterilization cycle involves observing gauges, displays, or computer printouts on the equipment for correct temperature, pressure, and exposure time. Heat-sensitive chemical indicators (e.g., those that change color after exposure to heat) do not ensure adequacy of the sterilization cycle, but they are useful in detecting major unit malfunctions or human errors during sterilization procedures. These chemical process monitors should be used when processing instruments. Each pack should have an internal chemical indicator to verify that the sterilant has penetrated the packaging material. If an opaque packaging material is used and the internal indicator will not be visible on the outside of the package, an external indicator such as sterilization tape should be placed on the package. Indicators provide a quick, easy way to visually identify if the package was processed through a sterilizer. If either the external and/or the internal indicator indicate inadequate processing, the item should not be used.[4,48]

The CDC *Guidelines for Infection Control in Dental Health-Care Settings, 2003*recommend that sterilization cycles should be verified for each sterilizer by the periodic use (at least weekly) of BIs (spore tests).[4] In the case of implantable devices, each load should be biologically monitored. The CDC *Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008*is in agreement with the at least weekly testing recommendation but add that if a sterilizer is used frequently (e.g., several loads per day), daily use of BIs allows earlier discovery of equipment malfunctions or procedural errors and thus minimizes the extent of patient surveillance and product recall needed in the event of a positive BI.[48]

Consequently, larger or busier dental practices that sterilize multiple instrument loads each day may have to consider daily instead of weekly use of BIs. BIs containing heat-resistant spores provide the best challenge for sterilization cycles. Two species are used, *Geobacillus stearothermophilus*and *Bacillus atrophaeus* (formerly *Bacillus stearothermophilus*and *Bacillus subtilis*). A spore vehicle designed for one sterilization method is not necessarily the proper modality to use for other units. Calibrated *G. stearothermophilus*spore-impregnated paper strips or glass vials are the appropriate biological monitors for autoclaves and unsaturated chemical vapor sterilizers, whereas*B. atrophaeus*preparations provide effective challenge for conditions in dry heat sterilizers and EO units. Proof of destruction of these resistant microbial forms is used to infer that all microorganisms exposed to the same conditions have been destroyed, representing the most sensitive check of sterilizer efficiency.[2,4,8,9,11,12,48]

Environmental Surface and Equipment Asepsis

Many operatory surfaces become contaminated with patient blood, saliva, and other materials during dental treatment. The decontamination of these operatory treatment surfaces between patient appointments constitutes an important component of an effective infection prevention and control

program.[4,48] The routine use of chemical disinfectants, disposable barriers, or both is warranted in certain instances because it is not possible, or necessary, to sterilize all contaminated items or surfaces.

A standard system of classification for chemical sterilants and disinfectants was first proposed by Spaulding in 1972.[48] This system, originally devised for classifying hospital instruments according to their use and degree of contamination, was adapted to include dental instrument and equipment asepsis. A modification of the original scheme was published in 1991 and is presented in Table 53-4.[48] In addition to classifying patient care items, three levels of disinfection (i.e., high, intermediate, and low) are used for patient care devices that do not require sterility, and two levels (i.e., intermediate and low) are used for environmental surfaces. The intended use of the item in patient care determines the level of disinfection. Different classes of disinfectants are defined based on their effectiveness against vegetative bacteria, tubercle bacilli, fungal spores, lipid-containing and non-lipid-containing viruses, and bacterial endospores.

Antiseptic formulations may not be used as surface disinfectants. Surface disinfectants (e.g., sodium hypochlorite preparations, iodophors, complex or synthetic phenolics, dual quaternary ammonium compounds, and bromides) that are water-based sprays are better cleaners and disinfectants than alcohol-based foams and aerosols because the latter tend to evaporate faster, and the alcohol may hinder removal of bioburden.[48] A two-step process, or spray-wipe-spray technique, should be followed to clean (spray-wipe) and disinfect (spray) the surfaces.

To reduce waiting time between patients, disposable impermeable barriers may be used where appropriate. Disinfection should be performed between patients if the barrier is breached allowing surface contact with contamination (e.g., blood, saliva, or bioburden); otherwise, change of impermeable barriers is sufficient between patients. Commercially prepared cloth wipes are available that contain a range of disinfectant agents and can reduce the amount of disinfectant inhaled by DHCP. Contrary to the first generation of wipes, current wipes on the market stay moist longer and can be quite effective. Wipes containing high concentrations of alcohol may not be suitable as initial surface cleaners, and their ability to keep contact surfaces wet for required disinfection intervals should be considered before use. To be effective, at least two cloths must be used—one for cleaning (wipe-discard) and another for disinfecting (wipe) the surface.

The time of contact of the disinfectant with the surface is important, as is room temperature. Manufacturer's instructions must be followed with regard to the material compatibility, time, and temperature while using any chemical germicide.[48] It is not appropriate to make your own wipes with paper towels or gauze squares, as their composition can compromise the effectiveness of the disinfectant. Appropriate PPE must be worn during cleanup procedures to prevent DHCP from direct contact with these chemicals.

Barrier choices range from inexpensive plastic food wrap to commercially available custom-made covers. Included in the areas that may be covered are the equipment controls, chair switches, light handles, head rests, hand-handled soap dispensers, coupling areas of the air and water tubings for the air-water syringe, and the handpiece. Controls that are operated by foot need not be wrapped but may be cleaned during regularly scheduled housekeeping procedures.

Environmental surfaces can be divided into clinical contact and housekeeping surfaces (see Table 53-4). Clinical contact surfaces can be designated and protected with a disposable impermeable barrier. Electrical switches and nonsealed controls of equipment must not be sprayed directly with a disinfectant

but must be barrier-protected. If barriers are not used, surfaces should be cleaned and disinfected between patients using an EPA-registered low-level (with HIV and HBV claim) to intermediate-level (i.e., tuberculocidal claim) hospital disinfectant. If visibly contaminated with blood, environmental surfaces must be disinfected with an EPA-registered, intermediate-level hospital disinfectant (capable of killing *Mycobacterium tuberculosis, Pseudomonas aeruginosa, Salmonella enterica, Escherichia coli,* hydrophilic viruses, and lipophilic viruses).[2,4,49] General cleaning and disinfection of clinical contact surfaces, dental unit surfaces, and countertops at the end of the daily work activities also is recommended. To facilitate daily cleaning, treatment areas should be kept free of unnecessary equipment and supplies.

Most housekeeping surfaces need to be cleaned only with a detergent and water or an EPA-registered, detergent/low-level disinfectant, depending on the nature of the surface and the type and degree of contamination. Schedules and methods vary according to the area, surface, and amount and type of contamination.[3,4]

It is necessary to maintain and service equipment and replace consumables as prescribed by the manufacturers. The suction lines should be cleaned with a disinfectant or with enzymatic cleaners using protocols designated by the manufacturers. While using a saliva ejector, the patient should be instructed to avoid closing the mouth around it because it could cause a reverse/negative pressure, leading to suck-back of contaminants from the suction lines.[50,51,52] Hollow-bore instruments, such as air-water syringe tips, are difficult to clean and can retain bioburden inside the lumen. It may be more practical to use single-use disposable tips because they are inexpensive and easy to change.

Water Quality

Since the 1960s, dental unit water systems (DUWS) have been known to be contaminated by nonpathogenic and pathogenic organisms. DUWS are contaminated by organisms that colonize the system and water lines and soon after form biofilms inside the lumens of the water lines.[53] Although the water coming into the system from an external source is of potable quality (less than 500 cfu/mL of bacteria and less than 1 coliform), water coming out of the units may be contaminated to 1 million cfu/mL. This contamination occurs because dental unit water line factors (e.g., system design, flow rates, materials) promote bacterial growth and development of biofilm (see Figure 53-4).

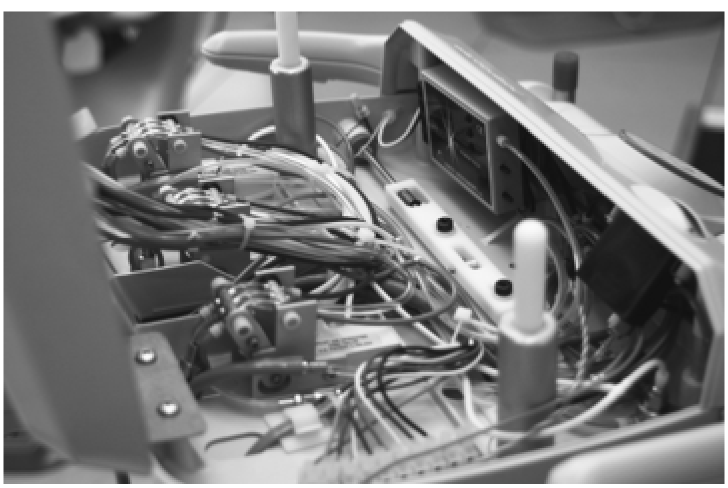

Figure 53-4.

Disassembled bracket tray showing air and water lines and antiretraction valves to minimize retraction of fluids back into the ¨

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Investigators have identified multiple classes of organisms in DUWS samples, ranging from a nonpathogenic to a pathogenic spectrum of microbes.[54] Types of microbes commonly associated with the DUWS water are *Bacterionema* spp.; *Corynebacterium* spp.; Gram-negative bacilli and cocci; *Klebsiella* spp.; *Neisseria (N. catarrhalis)*; *Pseudomonas* spp., including *P. aeruginosa, P. pyogenes,* and *Burkholderia cepacia*; *Staphylococcus epidermidis*; *Streptococcus mutans, Streptococcus salivarius,* and *Streptococcus mitis*; *Actinomyces* spp.; *Enterococcus* spp.; α-hemolytic streptococci; *Staphylococcus aureus*; *B. subtilis*; *E. coli*; *Flavobacterium*;

nonhemolytic streptococci; *Legionella pneumophila*; *Mycobacterium*spp.; *Aspergillus niger*; *Cladosporium*; *Achromobacter*; and *Alcaligenes faecalis*.

To date, there is no published evidence of serious health problems for either patients or DHCP from contact with dental water except a brief Italian case report published in 2012 describing the first documented case of a dental patient with *Legionella pneumophila*infection from colonized water used during treatment. The environmental investigation isolated the same virulent *Legionella*strain from both the patient's bronchial aspirate and the dental practice's high-speed handpiece waterlines and not from any other potential sources.[55]This incident serves to reinforce the importance of ongoing efforts of the healthcare profession to implement and use effective infection prevention and control precautions. Human infections caused by waterborne microorganisms such as *Legionella pneumophila*have been described over a number of years in municipal, personal, and healthcare environments. No one ever said this type of potentially life-threatening infection could not happen in a dental setting. The maze of small-bore plastic tubing that delivers water in a dental unit offers an optimal environment for the proliferation of complex microbial populations known collectively as biofilm. When a complete infection prevention and control system is used to treat dental water, one can minimize or prevent organisms from attaching, colonizing, and proliferating on the inner surfaces of the tubing.

Exposing patients or DHCP to water of poor microbiological quality is inconsistent, however, with universally accepted infection prevention and control principles and the high level of asepsis standards routinely exhibited in most dental facilities.[4,54]In 1995, the ADA issued a draft statement on the quality of water used in dental treatment, encouraging industry and researchers to improve the design of dental equipment and to provide equipment with the ability to deliver treatment water with 200 cfu/mL or less of unfiltered output from water lines.[56]Similar standards are in effect for dialysate used in hemodialysis units. Standards also exist for safe drinking water quality as established by the EPA, the American Public Health Association (APHA), and the American Water Works Association (AWWA), which set limits of no more than 500 cfu of heterotrophic bacteria per mL of drinking water.[57,58]The number of bacteria in water used as a coolant/irrigant for nonsurgical dental procedures should be as low as reasonably achievable and, at a minimum, less than the 500 cfu/mL regulatory standard for safe drinking water established by the EPA and the APHA/AWWA.[4,57,58]

Successful engineering and manufacturing of these and other options for improving water quality continue to provide DHCP with multiple choices for exerting better control over the quality of source water used in patient care. These choices are as follows:

1. An alternate water supply that bypasses community water systems and DUWS by providing sterile or distilled water directly into water line attachments (i.e., separate reservoir) combined with chemical treatment
2. Filtration involving in-line filters to remove bacteria immediately before dental unit water enters instrument attachment
3. Chemical disinfection involving periodic flushing of lines with a disinfectant followed by appropriate rinsing of lines with water or a continuous-release chemical disinfection system
4. Thermal inactivation of facility water at a centralized source
5. Reverse osmosis or ozonation using units designed for either single-chair or entire-practice water lines
6. Ultraviolet irradiation of water before entrance into individual unit water lines

Two levels of care in dentistry are based on the extent of surgery and the exposure of underlying bone. For treatment that does not expose bone, and when extensive surgery (e.g., incision, excision, or reflection of tissue exposing normally sterile areas of the oral cavity) is not performed, the water can be of potable quality (up to 500 cfu/mL) and not sterile. For treatment that exposes bone or when performing extensive surgeries (e.g, biopsy, periodontal surgery, apical surgery, implant surgery, surgical extractions of teeth), sterile water or saline should be used to decrease risk of postoperative infection.[4]

The water delivery system must be sterile to avoid contaminating the water or saline used in surgery. Filtered water and bacteria-free water are not sterile water, and filtered or distilled water is not to be used in this instance.[54] Conventional dental units cannot reliably deliver sterile water even when equipped with independent water reservoirs because the water-bearing pathway cannot be reliably sterilized. Sterile water delivery devices should be used to deliver sterile water.[2,4] Sterile water systems for surgery and for dental implants bypass the dental unit and employ sterile disposable or autoclavable tubing. Oral surgery and implant handpieces and ultrasonic scalers that deliver sterile water or other solutions using sterilizable tubing or that are single-use disposable are commercially available.[54]

DENTAL RADIOGRAPHY ASEPSIS

Multiple opportunities for cross-contamination of equipment and environmental surfaces exist when taking and developing dental radiographs. Gloves should be worn when taking radiographs and handling contaminated film packets. Other PPE (e.g., mask, protective eyewear, protective clothing) is required when spatter or splashing of blood or other potentially infectious materials is anticipated.[2,3,4,5,9,10,59,60]

Even where there is no generation of splash or spatter, it is suggested to wear a mask when taking radiographs. Because of the close proximity to the oral cavity during the procedure, respiratory infections can be transmitted to DHCP.

After exposure of dental radiographs, care must be taken when handling the contaminated films. If protective covers are used over films during exposure, the following steps are performed[59,60]:

1. While wearing gloves, remove and discard the covers without contaminating the film.
2. Remove gloves and perform hand hygiene.
3. Process the films.

If protective covers are not used over films during exposure, the following steps are performed[9,59,60]:

1. While wearing gloves, place the contaminated films into a container.
2. Remove gloves and perform hand hygiene.
3. Don a fresh pair of gloves and transport the container to the darkroom.
4. Carefully open the film packet and drop the films on a clean surface.
5. Discard the contaminated film packet wrappers.
6. Remove gloves and perform hand hygiene.
7. Process the films.

Surface cleaning and disinfection procedures for radiography equipment are the same as in the dental operatory. Using impermeable disposable surface barriers is encouraged, especially on surfaces that are difficult to clean and disinfect (e.g., x-ray control panels), and can be considered a time-saving procedure. Lead aprons and thyroid shields should be cleaned and disinfected if they become contaminated.[9,10]

Digital radiography sensors and associated computer hardware vary by manufacturer or type of device in their ability to be cleaned and disinfected or sterilized. Manufacturer instructions must be followed with regard to cleaning, disinfecting, and sterilizing these types of equipment. These items should be barrier protected to reduce contamination to a minimum. Also, because barriers do not always protect from contamination after removing the barrier, the device should be cleaned and disinfected with an EPA-registered hospital disinfectant (intermediate-level) after each patient.[4,61,62,63,64]

DENTAL LABORATORY ASEPSIS

Most items requiring infection prevention and control procedures in the dental laboratory either originate in the operatory or are returned to the treatment area from the laboratory. Gloves must be worn when handling contaminated laboratory items, and care must be taken to prevent gloves from being caught in lathes, model trimmers, or other rotary equipment. Other PPE (e.g., mask, protective eyewear, protective clothing) is required when spatter or splashing of blood or other potentially infectious materials is anticipated.[3,9,10]Protective eyewear, safety shields, and adequate ventilation are required when using rotary equipment to reduce the risk of injury from aerosols, spatter, and macroscopic particles.

Communication between the dental office and the laboratory concerning infection prevention and control procedures (e.g., disinfection protocol of impressions or appliances) is essential.[4,65]Materials that are not decontaminated are subject to OSHA regulations regarding transport and shipping of infectious materials.[3]

Laboratory work should be done only on prostheses, appliances, or impressions that have been properly cleaned and disinfected. Bringing contaminated items into the laboratory increases the changes of cross-contamination.[10]Materials, impressions, and intraoral appliances must be cleaned (i.e., rinsed with running tap water) first to remove contaminant blood and saliva, then disinfected, followed by a final rinse to remove all residual disinfectant. No single disinfectant is ideal or compatible with all impression materials or appliances (see Table 53-6).[9]It is advisable to consult with manufacturers regarding the stability of specific materials during disinfection. When using ultrasonic cleaners, the item should be placed in a sealed, disposable plastic bag, inside a beaker that is compatible with the ultrasonic machine, and processed. After removal from the ultrasonic cleaner, the technician disposes of the cleaning solution and disinfects or sterilizes the item before returning it to the patient. Prostheses, appliances, and other items constructed in the laboratory that are to be inserted into the patient's mouth must be cleaned and disinfected or sterilized before delivery to the patient.

Table 53-6 Guide for Selection of Appropriate Disinfection Methods for Items Transported to or From the Dental Laboratory

Item	Method*	Recommended Disinfectants	Comments
Articulators, facebows	Spray-wipe-spray	Chlorine compounds or iodophors	Facebow forks should be heat sterilized before reuse

Casts	Spray until wet or immerse	Chlorine compounds or iodophors	Disinfectant can be prepared using slurry water (saturated calcium sulfate); should not be disinfected until fully set (24 hours); do not ship until fully dried
Custom impression trays (acrylic)	Immerse or spray until wet	Chlorine compounds, iodophors, or phenolics	Do not reuse! Discard
Impressions	Immersion disinfection preferred		Heat sterilize reusable impression trays; discard plastic trays after use
Irreversible hydrocolloid (alginate)	Use caution with immersion disinfection; use only disinfectants having short-term exposure times (no more than 10 minutes for alginates)	Chlorine compounds or iodophors; phenolic sprays may be used on alginates	
Reversible hydrocolloid	Use caution with immersion disinfection; use only disinfectants having short-term exposure times	Chlorine compounds or iodophors	Do not immerse in alkaline glutaraldehyde†
Polysulfide rubber, silicone rubber	Disinfect by immersion	Glutaraldehydes,†chlorine compounds, iodophors, phenolics	Disinfectants requiring more than 30 minute exposures not recommended
Polyether	Disinfect by immersion with caution; use only disinfectants having short-term exposure times (no more than 10 minutes)	Chlorine compounds, iodophors, or phenolics	ADA recommends any of the disinfectant classes; however, short-term exposures are essential to avoid distortion
Zinc Oxide Eugenol impression paste	Disinfection by immersion preferred; spraying can be used for bite registrations	Glutaraldehydes†or iodophors	NOT compatible with chlorine compounds; phenolic sprays may be used

Impression compound	Disinfection by immersion preferred; spraying can be used for bite registrations	Iodophors or chlorine compounds	Phenolic sprays can be used
Prostheses	Immerse in disinfectant; use caution to avoid corrosion of metal; **NEVER**expose unglazed porcelain to any disinfectant (must handle as contaminated)		Clean "old" prostheses by scrubbing with hand-wash antiseptic or sonication before disinfection
Removable (acrylic/porcelain)		Chlorine compounds or iodophors	Rinse thoroughly after disinfection; store in diluted mouthwash
Removable (metal/acrylic)		Chlorine compounds or iodophors	Rinse thoroughly after disinfection; store in diluted mouthwash
Fixed (metal/porcelain)		Glutaraldehydes,[†]chlorine compounds, or iodophors	Rinse thoroughly after disinfection
Shade guides	Immerse or spray-wipe-spray	Iodophors or phenolics	Final wipe with water or alcohol to avoid discoloration
Wax rims, wax bites	Rinse-spray-rinse-spray	Iodophors or phenolics	Rinse again after disinfection

*Exposure time to disinfectant should be that recommended by the disinfectant manufacturer. All items must be thoroughly rinsed (15 sec minimum) under running tap water following disinfection.
[†]Glutaraldehye-based products should only be used if another disinfectant is not readily available. When used, appropriate precautions including closed containers to limit vapor release, wearing chemically resistant gloves and aprons, face shields, and having adequate ventilation are essential. All items must be thoroughly and carefully rinsed.
From Merchant VA. Dental laboratory infection control: OIC update. *Dent Learn Syst*1995;3:1–8.
ADA, American Dental Association.

Laboratory items (e.g., burs, polishing points, rag wheels) used on contaminated or potentially contaminated items should be single-use disposable or heat sterilized. Heat-tolerant items used in the mouth (e.g., facebow forks, orthodontic pliers, metal impression trays) should be heat sterilized before being used on another patient.[4]Items that do not normally contact the patient or the prosthetic appliance

but frequently become contaminated and cannot withstand heat sterilization (e.g., articulators, case pans, lathes) should be cleaned and disinfected.

Surface cleaning and disinfection procedures for laboratory equipment are the same as in the dental operatory. Using disposable surface barriers is acceptable on environmental surfaces or equipment (e.g., pumice pans) when contamination is anticipated.[9,10]

WASTE MANAGEMENT

Dental facilities routinely generate a variety of waste materials, which may range from noninfectious to infectious, hazardous, or toxic. The implementation and application of logical procedures in safely handling, storing, and disposing of waste items further minimize occupational risks to HCP, reduce exposure to the public, and protect the environment.[11,66] Terms have been developed to describe different waste categories (see Table 53-7).[11] The following suggestions may assist personnel in using appropriate federal, state, and local regulations:

1. All waste must be discarded in accordance with applicable federal, state, and local regulations.
2. In general, blood-stained and saliva-stained items are not considered regulated medical waste.
3. Items saturated with blood and/or saliva (i.e., fluid can be expelled with squeezing or dried substance flakes off) and items caked with dried blood or saliva are considered regulated medical waste.
4. With regard to biohazard communication, containers with regulated medical waste must be labeled with the appropriate biohazard symbol. Included in this category are sharps containers, contaminated pans used for cleaning bioburden-laden instruments, bags of contaminated laundry, and specimen containers.
5. Used needles and other contaminated sharps must be placed in a puncture-resistant, leakproof container that is closable and contains a biohazard label or is red in color.
6. Unfixed tissue and teeth must be discarded into containers or bags that are closable and leakproof and contain a biohazard label or are red in color. Extracted teeth containing dental amalgam should not be placed in a medical waste container that uses an incinerator for final disposal. State and local regulations should be consulted regarding disposal of the amalgam. DHCP are encouraged to review the ADA *Best Management Practices for Amalgam Waste*for additional information on handling and disposing amalgam waste.[67]
7. If liquid blood is collected in a canister, it must have a biohazard label.

Table 53-7 Glossary of Waste Management Terms

Contaminated waste	Items that have had contact with blood or other body secretions
Hazardous waste	Waste posing a risk or peril to humans or the environment
Infectious waste	Waste capable of causing an infectious disease
Medical waste	Any solid waste* that is generated in the diagnosis, treatment, or immunization of humans or animals in research pertaining thereto or the production or testing of biologicals. The term does not include hazardous waste or household waste. Only a small percentage of medical waste is infectious and needs to be regulated
Regulated waste	Infectious medical waste that requires special handling, neutralization, and disposal
Toxic waste	Waste capable of having a poisonous effect

* Solid waste includes discarded solid, liquid, semiliquid, or contained gaseous materials.
From Miller CH, Palenik CJ. *Infection Control and Management of Hazardous Materials for the Dental Team*. 2nd ed. St Louis, MO: Mosby, 1998.

For further information, see **113. Waste Management**.

Summary

Effective infection prevention and control must occur as a routine component of DHCP activities. Much has been accomplished over the years. Implementation and routine application of a vast array of logical, effective techniques and procedures have served to protect DHCP and patients who expect safe care. Recognition, understanding, and compliance with appropriate recommendations by DHCP, health professional organizations, and regulatory governmental agencies continue to have a major impact on the way dental treatment is provided. The field of infection prevention and control is constantly changing with the development of new products and techniques. Readers should periodically review publications of new or updated guidelines and documents to stay informed of current infection prevention and control recommendations and practices as new information and technologies become available. It is important to respond to emerging challenges in this area not only by realizing the success of the practices called for years ago, but also by realizing we must remain current in infection prevention and control approaches.

Future Trends/Research

Research is needed in these areas:

1. Develop and evaluate new devices and dental equipment with safety features and protective barriers.
2. Continue research to develop latex alternative materials.
3. Continue to explore appropriate barrier protection and chemical disinfection methods for heat-sensitive semicritical patient care items.
4. Determine the frequency of surface contamination on barrier-protected items (e.g., digital radiography sensors, intraoral photography equipment).
5. Evaluate the effects of repetitive reprocessing cycles (i.e., automated cleaning and heat sterilization) on burs and endodontic files.
6. Continue research to identify safe, effective, and economical approaches to improving and maintaining the quality of DUWS.

Supplemental Resources

Kohn WG, Collins AS, Cleveland JL, et al. Guidelines for infection control in dental health-care settings–2003. *MMWR Recomm Rep*[serial online]. 2003 Dec 19;52(RR-17):1–61. Available at: **http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5217a1.htm**.

Molinari JA, Harte JA. *Cottone's Practical Infection Control in Dentistry,* 3rd ed. Baltimore: Lippincott, Williams & Wilkins, 2009.

Miller CH, Palenik CJ. *Infection Control and Management of Hazardous Materials for the Dental Team*, 5th ed. St. Louis: Mosby, 2014.

WEB-BASED RESOURCES

American Dental Association (ADA). Available at: **www.ada.org**/

ADA Dental Infection Control Issues. Available at: **www.ada.org/2697.aspx**.

Association for Professionals in Infection Control and Epidemiology (APIC). Available at: **www.apic.org**.

Centers for Disease Control and Prevention (CDC). Available at: **www.cdc.gov**.

CDC: Dental Infection Control. Available at: **www.cdc.gov/OralHealth/infectioncontrol/index.htm**.

Environmental Protection Agency. Available at: **www.epa.gov**.

Food and Drug Administration. Available at: **www.fda.gov**.

National Institute for Occupational Safety and Health (NIOSH). Available at: **www.cdc.gov/niosh**.

Occupational Safety and Health Administration (OSHA). Available at: **www.osha.gov**.

OSHA Dental Safety and Health Topics. Available at: **www.osha.gov/SLTC/dentistry/index.html**.

Organization for Safety, Asepsis, and Prevention (OSAP). Available at: **www.osap.org**.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Emergency and Other Pre-hospital Medical Services

Author(s): William E. Coll, M, PUB, AFF, BA, LP
Program Manager - Infection Preventionist

Austin/Travis County EMS
Austin, TX

Katherine West, BSN, MSEd
Infection Control Consultant

Infection Control/Emerging Concepts Inc
Manassas, VA

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Abstract

The issues of infection prevention are not significantly different in the prehospital setting from those of the hospital environment. The major differences are the dynamic and unstructured environments in which emergency field responders are required to work. Today, ambulances are compact emergency departments that can provide state-of-the-art medical care both on the scene and during transportation to a medical facility. The prehospital care providers comprise not only paramedics and emergency transport personnel but also various first responder components: fire departments, police agencies, corporate emergency response teams, volunteers, those involved in public access automated external defibrillation programs, and citizen rescuers. The scope of practice for the public safety arena extends far beyond just patient care and involves many facets. Risk for contact with biological hazards can occur in a variety of situations; from an officer in direct contact with individuals during restraint for arrest to individuals involved in the collection and inventory of property and evidence. As healthcare evolves in the United States, the role of emergency medical service personnel in providing care to the community will also expand with the concept of community para-medicine in the near future.

Key Concepts

- A systematic approach of early recognition/notification, rapid response, and patient stabilization has decreased morbidity and mortality of patients nationwide.

- Four primary models are used to deliver emergency medical services: fire department based, hospital based, private provider, and separate third service.
- Paramedics and emergency care personnel are associated with the transport of patients, and other first responder components include fire departments, police agencies, corporate emergency response teams, volunteers, those involved in public access automated external defibrillation programs, and citizen rescuers. Although most of the issues of infection prevention are the same, each particular segment presents with some specific concerns.
- Infection prevention is a continuum from initial patient contact through all phases of patient care and must be practiced not just for provider safety but to ensure safety for the patient.
- Ensuring that there is adequate and timely communication across healthcare settings helps address the unique infection transmission risks experienced by emergency responders. These are of special concern when an exposure event has occurred.
- The recommended vaccines and immunizations for fire/emergency medical services personnel follow the same Centers for Disease Control and Prevention recommendations for all members of the healthcare team.
- The passage of the Ryan White Notification Law ensures the sharing of information regarding exposures between medical facilities and the fire/emergency medical services or law enforcement designated officer for infection control.

Background

In 1990, the U.S. Congress passed the Ryan White Act (Public Law 101–381). Subpart II of the law addresses the process for notification of fire and emergency medical services (EMS), volunteers, and law enforcement personnel for exposure situations. This law lays out a procedure for the sharing of information on the source patient and gives time frames for this process. The procedure outlined is an excellent basis for building a comprehensive and effective communications system. This system should currently be in place in all states.

In December 2005, the Notification of Exposure subpart of the Ryan White Law was deleted. In 2009, the Ryan White Notification Law was re-instated. However, the U.S. Congress determined that this would be a new law and that the Centers for Disease Control and Prevention (CDC) needed to develop a new list of diseases. The CDC completed this task in November 2011 and the new expanded list of diseases was published in the *Federal Register*on November 2, 2011. This new list requires that medical facilities notify the designated infection control officer (DICO) of the fire/EMS services if they have transported a patient suspect for or diagnosed with one of the airborne or droplet diseases on the list.

Compounding the usual infection prevention issues, the issue of bioterrorism has many responders recognizing the role they play as the early warning sentinels for identifying potential outbreaks or attacks. Raising an index of suspicion early in the contact with a patient and recognizing an increased number of patients from a similar response type can trigger prompt community efforts at containment and isolation.

Basic Principles

Infection prevention practice has become part of the standard EMS training curriculum. However, integration of EMS with other community infection professionals and the establishment of efficient

communication networks for information sharing still need to be developed in many locations.

The delivery of prehospital emergency medical care varies, but there are typically four models: (1) fire department based, (2) hospital based, (3) private provider, and (4) separate third service. Within the different systems, the level of training and certification of the providers determines the level of care provided within the system.

In various parts of the country, volunteers provide EMS care. The ability of such organizations to develop and implement a comprehensive infection prevention program can be limited. With the delivery of patient care by nontraditional providers, there are situations in which exposure follow-up is hampered. The ability to assist with exposure follow-up for the general public is limited by the scope of the federal and state statutes outlining the notification process for emergency care personnel potentially exposed to an infectious agent.[1]

The Ryan White Comprehensive AIDS Resource Emergency Act of 2009 (Pub Law No. 111-87, Part G) advances a procedure for sharing information following exposure incidents beyond what is required under the Occupational and Safety Health Administration's (OSHA) bloodborne pathogen regulation and the CDC TB Guidelines of 2005 as many airborne and droplet diseases have been added to the list. Table 54-1 shows a comparison between the Ryan White Law and the OSHA bloodborne pathogens regulation. This is especially important for states that do not have their own OSHA state plan. States that do not have an OSHA state plan offer no coverage to state and municipal employees. Therefore, the Ryan White Act is essential for healthcare providers in public safety.

In the fire and EMS discipline, the infection prevention concept of Standard Precautions has been adopted on a national basis. This maintains consistency with all other healthcare disciplines.

Providers should consider the following steps on all patient interactions:

- Maintain a heightened awareness to the potential for interface with patients with new and resistant organisms.
- Obtain a thorough travel history that covers 1 to 6 months.
- Conduct active surveillance for infected sores, ulcers, lesions, and drainage that may or not be contained by dressings.
- Specifically examine sites of recent surgical or other invasive interventions.
- Cover any openings exuding or secreting drainage.
- Wear the appropriate level of personal protective equipment (PPE) based on the mode of transmission of the suspect agent.
- Where respiratory vectors are considered, employ PPE in accordance with the Droplet/Airborne Precautions.
- Ensure that the patient is "wrapped" prior to being moved to minimize environmental contamination.
- Confirm that the hospital or other receiving facilities have been notified of the possibility of an infectious communicable disease.
- Perform thorough cleaning of all equipment that had contact with the patient, the environmental surfaces, or high-touch items/areas.
- Understand the need for diligence in hand hygiene.

Table 54-1 Ryan White/OSHA Comparison Chart

Quick Reference – Updated 2011

Comparison of Ryan White Notification Law and OSHA

Ryan White Notification Law	OSHA Bloodborne Pathogens & TB
Requires a liaison person for exposures (designated officer)- 24/7	States a person should be charged with program management
Sets up a step-by-step process for hospitals and departments to follow	States compliance is "performance-based" does not give a set process
Gives coverage to volunteers	No clear coverage for volunteers
Covers all emergency response employees in all states	Does not give coverage in states that do not have their own state OSHA plan
Gives set time frames for medical facilities to turn test results around	Does not give set time frames- refers to CDC guidelines
Requires medical facilities to notify emergency response employees if they transported a person suspect or confirmed for airborne & droplet transmitted diseases	Not noted by OSHA
Gives an administrative process for medical facility noncompliance	No administrative process
States medical examiner responsibilities for testing deceased persons if an exposure occurred	Not addressed
States designated officer makes the first call on an exposure	Not addressed
States medical facilities have responsibility to test the source	Not as clear
Requires hospitals notify the DICO regarding airborne & droplet transmitted diseases	Only addresses HIV, HBV, HCV, syphilis, and TB

HISTORY OF EMERGENCY MEDICAL SERVICES

The concept of rapid transport and treatment of the injured developed primarily in the military contexts of the Napoleonic and American Civil Wars.[2] After the Civil War, the application of transport and treatment by ambulance began to take hold across the country. In the earliest stages, ambulances responded from hospitals or police stations. Cleveland, Ohio, began an ambulance service dependent on undertakers. Undertakers remained a common provider until the late 1950s and early 1960s.[3] Of interest, 19th-century ambulances routinely refused service to "infectious" patients, such as those with smallpox. Instead, a different vehicle, horse-drawn hearses known as Black Marias, transported discernibly infectious patients to isolation facilities.

The increased focus on cardiac-related deaths and trauma associated with motor vehicle collisions in the mid-1960s began the rapid evolution of an organized EMS system.[3] The funding of basic emergency medical training and the introduction of mobile coronary care units established the national standards for EMS services. Today, ambulances are compact emergency departments that can provide state-of-the-art medical care on-scene and during transportation to a medical facility. A systematic approach of early recognition and notification, rapid response, and patient stabilization has decreased morbidity and mortality nationwide.[3]

In late 1978, the National Library of Medicine was commissioned to conduct a search of the literature for information related to infection prevention practices and techniques to the provision of EMS in the United States. No information was located, and a new area of need was identified. The first published article addressing infection prevention practice in the field of EMS was published in the January–February 1983 issue of *Journal of Emergency Medical Services.*[4]

A renewed literature review continues to identify limited writings regarding infection prevention within EMS. The review identified several articles reporting on environmental contamination with bacterial organisms such as *Staphylococcus*, the role of EMS in infectious disease prevention, and the rate of healthcare-associated infections (HAIs) among EMS patients admitted to hospital.[5,6,7,8,9]

The recognition of the universal lack of infection prevention practices opened the door for infection preventionists (IPs, formerly "infection control professionals") to extend their practice arena. The first published article addressing this opportunity appeared in the *American Journal of Infection Control*in April 1983.[10]This article outlined the possible expansion of the IP's role as a liaison to another discipline as an important part of the healthcare team. Unfortunately, few IPs sought to extend their job functions to include this discipline, even though EMS is the entry point for many patients at high risk for HAIs, especially trauma patients.

The publication of the CDC's *Guidelines for Prevention of Transmission of Human Immunodeficiency Virus and Hepatitis B Virus to Health Care and Public Safety Workers*in 1989[6]and the OSHA's *Bloodborne Pathogens Standard*[11,12]helped highlight the importance of infection prevention in EMS and fire services. Also in 1989, the National Fire Protection Association (NFPA) published its first version of an infection control standard for fire service.

Additionally, the National Institute for Occupational Safety and Health (NIOSH) published information relating to p reventing exposures to bloodborne pathogens among paramedics.[13]Infection prevention practice has since become part of the standard EMS training curriculum. However, many departments do not have trainers well prepared to teach this information. This need has become more evident with the resurgence of previously managed diseases such as pertussis, measles, and mumps and the emerging diseases of severe acute respiratory syndrome (SARS), avian influenza, and novel H1N1.

In many locales, the duties for infection prevention issues are relegated to the EMS department safety officer. The scope of issues confronting any safety officer can overwhelm the desire to be competent in all arenas of safety. Infection prevention may be reduced in importance, more by a lack of knowledge of infectious diseases than a lack of commitment. To reduce the burden placed on the safety officer and to focus more attention on infection prevention, many departments are identifying individuals and ensuring adequate training for a DICO. This is in keeping with the Ryan White Law in Part G addressing notification of EMS providers and the National Fire Protection Standard 1581 for the handling of exposure events.

The 2013 version of National Fire Protection Standard 1582 incorporates the need for vaccines and immunizations.[14]Some departments are hiring nurses with infection prevention training to assist in what has been identified as an important part of employee safety and health. NFPA standards—*NFPA 1500 Standard on Fire Department Occupational Safety and Health Programs*and *NFPA 1581 Standard on Fire Department Infection Control Programs*[15,16]address these issues.

With the strong focus on bloodborne pathogens and use of PPE for healthcare personnel protection, there now needs to be a focus on protecting the patient from infection. Understanding the dynamics of disease transmission and the role each healthcare provider plays should be a key element in training and daily work practice. Training has been fear based and now needs to be evidence based.

DELIVERY MODELS

The delivery of prehospital emergency medical care varies across the country. Typically four models are used to deliver EMS: fire department based, hospital based, private provider, and separate third service.

FIRE DEPARTMENT-BASED MODEL

The fire service is the primary provider of EMS in U.S. and Canadian cities. As the number of actual fires has decreased, the service has shifted into an expanded role in emergency medical response. A national survey of paid U.S. and Canadian fire departments found that 90 percent of firefighters provide some level of medical care within their local community.[16] Most departments provide a basic first response role, whereas some have evolved an expanded scope, providing initial advanced life support (ALS) care on the scene. Transport is provided either by the fire service or by referral to a private ambulance company.

HOSPITAL-BASED MODEL

The provision of EMS by hospitals has been a staple for many years. The use of hospital-based ambulances began as an extension of the medical residency programs. Interns responded from the hospital and cared for the patient on the scene, then transported the patients to the hospital. Eventually, patient care was relegated to emergency medical technicians (EMTs). Such programs may provide specialized transport services, including neonatal intensive care, helicopter transport for trauma patients, and ambulatory transfer services for outpatients.

PRIVATE PROVIDER MODEL

Such providers are privately owned, for-profit companies or corporations that engage in the provision of medical transportation or EMS. Many private providers focus on the nonemergency transfer of patients from various nursing care facilities to physician offices or medical facilities. In some locations, the private providers operate as the emergency transport provider under contract from the municipality or county government. The governmental entity subsidizes the provider for a portion of the uncompensated care that the emergency market produces.

SEPARATE THIRD-SERVICE MODEL

Some jurisdictions provide EMS via a third public safety agency model. Under this model, the functions of EMS are separate from those of the fire department and law enforcement agencies. Third-service providers hire medical personnel whose sole purpose is to provide emergency medical care as a way to avoid enlisting personnel, usually firefighters, into a job/task many do not want to perform.

Such a model can provide stability among the workforce and permit the professional development of enhanced patient care skills. Many times, this model also employs the concept of a tiered response. The determination of resource response is made through medical priority dispatch. High-priority responses receive a coordinated response of fire service first responders, followed by ALS providers.

PROVIDER CERTIFICATION LEVELS

Within the different systems, the level of training and certification of the providers determines the level of care provided within the system. There are five basic levels of certification: emergency medical responder (EMR), EMT, advanced EMT, paramedic (P), and critical care nurse. The curriculum for each level is based on specific educational competencies that must be attained; however, there are recommended training ranges.

EMR is designed for individuals who, as part of their public safety duties, respond to medical or trauma emergencies. Individuals typically certified at this level are highway patrol officers, police officers, and volunteer first responders. The usual duration of this training should be in a range of 48 to 60 hours.[17]

EMTs are individuals who may serve in a role as first responders or providers in the care and transport of patients. Individuals certified at this level are firefighters and ambulance attendants. The duration of this training is in a range of 150 to 190 hours.[17]

Advanced EMTs provide advanced medical interventions to patients in the form of intravenous therapy and advanced airway management. The typical individuals certified at this level are EMTs who, by system design, are first responders or part of a tiered response who, because of extended response times or the remoteness of the service area, can provide these interventions while more advanced providers are responding. The duration of this training is 150 to 250 hours and requires that the EMT certification be completed first.[17]

Paramedics provide ALS in a prehospital environment. The skills at this level include intravenous therapy, advanced airway management, electrocardiogram interpretation, and pharmacological therapy. Individuals certified or licensed at this level may be firefighters on paramedic engines or transport providers in any of the previously mentioned system configurations. Such training can exceed 600 hours.[17]

Critical care nurses are registered nurses who are integrated members of an aeromedical flight program such as a helicopter or fixed-wing aircraft. The intensive care expertise of the nurse, coupled with an expanded knowledge of infusion pump equipment and potent intravenous medications, complements the knowledge and skills of field paramedics.

VOLUNTEER STAFFING

In various parts of the country, volunteers provide EMS care. The certification levels of volunteers can include all of the levels previously discussed here. The ability of such organizations to develop and implement a comprehensive infection prevention and control program may be limited. Not having the resident expertise within the organization can restrict access to the appropriate resources available in the community.

If the expertise is not available in-house, accessing training or content expert input can be hit or miss. Sample infection prevention and control programs may serve as a template to articulate an organizational plan, but the nuances of infectious diseases may leave the department infection prevention officer unable to adequately address concerns raised by members. Such concerns may be addressed by consulting with hospital IPs and physicians. Local hospital facility IPs should consider providing assistance in facilitating the design and implementation of programs within volunteer agencies.

However, the IP must realize that what applies to a medical facility does not always apply practically to field care providers. In addition, time constraints can leave infection prevention education competing with myriad training and response topics. Education on infectious agents may be relegated to "just-in-time

training" rather than as part of an ongoing program of continuing infectious disease education. IPs should develop a clear understanding of the difficulties faced while in the field. This can best be achieved by doing a "ride-along"—going out on calls as an observer to develop first-hand understanding of the practice of EMS and the difficulties that can be encountered.

SCOPE OF THE PROBLEM

Although the design and structure of the various models may be different, the overall infection prevention concerns remain the same. In 2010, according to the U.S. National Fire Administration, 30,125 fire departments were registered in the National Fire Department Census Database.[18] The total firefighter census is 1,044,300 with a total of 30,098,000 responses, of which 65 percent or 19,803,000 were medically related responses. In addition, the U.S. Bureau of Labor Statistics estimates that as of 2010, 226,500 individuals were employed as EMTs or paramedics.[19] The staffing configurations for the provision of EMS can vary widely from location to location. The standard minimum for operation of a transport ambulance is two EMT providers. The combinations of EMT with an advanced EMT and paramedic depend on the availability of certified personnel at the desired level, the standard of medical care of the community, and the availability of funding. Approximately 48 percent of such personnel are employed with private services, 29 percent are government-based services, 17 percent are hospital-based services, and 6 percent are found within private industrial settings such as refineries and computer chip manufacturing facilities.[20] Information within the Canadian Fire Service regarding the number of departments and employees is collected at the provincial level and is not tracked nationally.

Although the potential risks for EMS personnel are fairly uniform, data on occupational exposures clearly indicate that, as with most healthcare providers, if an exposure occurs, there is a higher risk for seroconversion when the employee experiences a needlestick injury. However, with the passage of the Needlestick Safety & Prevention Law (PL – 106 – 430) and OSHA's enforcement on the use of needle safe devices, contaminated sharps injuries have greatly diminished in the provision of field care. Airway management, even at the basic level, can result in contact with respiratory secretions and close contact with exhaled organisms that could potentially result in an infection of an airborne or droplet disease. Therefore, all emergency care personnel are at risk for exposure to airborne or droplet infections.

Surveys have been conducted by groups and NIOSH of paramedics covering the years 2002–2003 to measure the incidence of exposure to blood among paramedics.[13] Twenty-two percent of all the paramedics surveyed had at least one exposure to blood in the previous year.

A large metropolitan EMS system has initiated performance measures that track the number of infectious disease exposures for both the EMS and fire departments. The measure is the number of exposures to blood and other potentially infectious materials per 1,000 EMS patient contacts. This measure is utilized to identify training needs and in evaluating the compliance with exposure prevention procedures.[21] The 5-year trend for the EMS department indicated an incidence rate from 0.24 exposures per 1,000 contacts in 2008 to an incident rate of 0.40 per 1,000 contacts in 2012. There were a total of 19 exposures during 91,769 patient contacts for 2012. Incidents involving sharps and tuberculosis (TB) represented the most exposures with five each. There were four exposures to nonintact skin, two to mucous membranes, and one human bite. The 5-year trend for the fire department indicated an incidence rate from 1.2 exposures per 1,000 contacts in 2009 to an incident rate of 0.40 per 1,000 contacts in 2012.[22] There were a total of nine exposures during 33,444 patient contacts. Incidents involving sharps represented the most exposures with three, followed by TB and mucous membrane exposures with two each. There was one exposure to nonintact skin, and one animal bite.

There still remains significant difference in the reporting of exposure incidents. NIOSH reports that during 2011, there were 6,400 EMS providers treated in emergency departments for exposures to harmful substances, which includes potentially infectious materials.[23]

The lack of concern to report exposures, coupled with a wide variance in what is an actual exposure, continues to indicate the real need for comprehensive occupational exposure studies of public safety personnel using sound criteria based on the CDC definitions of an exposure. In many departments, the CDC or OSHA definitions for an exposure are not being used. A common error is the use of OSHA's definition of "occupational exposure" instead of the correct definition, "exposure incident."

A study published in the *American Journal of Prevention Medicine*in 2001 reviewed 702 published articles addressing transmission of Hepatitis B virus (HBV) and Hepatitis C virus (HCV) in law enforcement, correctional, fire, emergency medical services, and healthcare personnel. A total of 105 articles were selected for full-text retrieval, and 72 were selected for inclusion. The data suggested that EMS providers were at risk for acquiring HBV, but the data failed to show an increased prevalence for HCV. EMS providers have exposure risks similar to those of hospital-based healthcare personnel. Other public safety workers appear to have lower rates of exposure.[24]

When we think of the infection prevention issues facing EMS, it is very easy to focus on only those associated with patient care. The scope of practice for the public safety arena extends far beyond patient care. As of 2010, The U.S. Fire Administration estimates that there are 1,044,300 individuals as firefighters. This includes volunteer and paid personnel.[18]Additionally, 37 percent of the fire services provide nontransport EMS services, and 20.5 percent participate in EMS ambulance transport. The Federal Bureau of Investigation (FBI) indicates that there are 1,001,984 sworn law enforcement officers in 14,633 agencies.[25]

There are many potential methods for those involved in public safety to be exposed to disease-causing agents. Such opportunities for exposures are one of the things that make infection prevention in the public safety sector a challenging and dynamic job. As the scope of responsibilities for public safety members has expanded, there has been a need to develop awareness and education for these up-and-coming infectious disease issues. It should be noted that the Ryan White Notification Law includes law enforcement and corrections officers.

With an increase in the delivery of patient care by nontraditional providers, there have been situations in which exposure follow-up has been hampered. The ability to assist with exposure follow-ups for the general public is limited by the scope of the federal and state statutes outlining the notification process for emergency care personnel potentially exposed to an infectious agent. When civilian "Good Samaritans" experience these exposures, they are not entitled to source patient test results in some states. Although it is unsettling, there has not been an outcry to change the existing procedures in those states to accommodate such Good Samaritan exposures. With the increase in automated external defibrillator (AED) programs, there may be increasing incidents that can result in possible exposures to civilian rescuers. All AED and ERT programs are required, under OSHA, to have post-exposure follow-up plans if these tasks are required in their job descriptions.[26]

THE RYAN WHITE COMPREHENSIVE AIDS RESOURCE EMERGENCY ACT OF 1990

In 1990, the U.S. Congress passed the Ryan White Comprehensive AIDS Resource Emergency Act of 1990 (Pub Law No. 101–381). Most IPs know this law with regard to acquired immunodeficiency syndrome (AIDS) education and funding for treatment. However, subpart II, now listed as Part G, addresses the process for notification of fire, EMS volunteers, and law enforcement personnel for exposure situations.

This law is one of the most important pieces of legislation ever enacted for members of this discipline because it sets the DICO as a liaison between the medical facility and the exposed department member. The DICO is charged with the task of ensuring that an actual exposure occurred and that proper care and counseling are rendered. This law lays out a procedure for the sharing of information on the source patient and provides specific time frames for this process. The procedure outlined by Part G is an excellent foundation for building a comprehensive and effective exposure communication system.[27]

Clearly, EMS and law enforcement are to follow their established procedures, not the medical facility procedures. This is important because the emergency response agency holds the liability if exposures are not properly followed up.[12] IPs need to be familiar with the contents of the law in order to (1) meet the federal requirements for exposure follow-up; (2) develop an ongoing relationship with the fire, EMS, or law enforcement officers who represent their department members; (3) develop in-house procedures for timely (rapid) laboratory work and information sharing; and (4) ensure that facility administration is aware of the law and the specific requirements it places on such a facility.

The Ryan White Act requires that each employer of emergency response personnel designate an individual to be responsible for managing exposure events. The overall goal is to ensure that there is a notification process for exposure situations and that the process is streamlined and timely. This individual is generally referred to as the DICO. This term is taken from the Ryan White Notification Law. Although the actual job description title may be different, such a description should stipulate the role as the DICO.

The DICO is the department's delegated lead person in the exposure investigation and notification process and for ensuring that proper care and medical treatment is rendered to the exposed employee. The medical facility and its staff members should work in conjunction with the DICO. Many DICOs have received formal training to prepare them for this role. In essence, they function much like medical facility IPs. However, many agencies have simply named an individual but have not offered the necessary formal training. Some states, such as Virginia, have made DICO training a required component for compliance.

The new disease listing for notification from the CDC under the Ryan White Notification Law is as follows:

Bloodborne:

- HCV
- HBV
- HIV
- Vaccinia virus
- Cutaneous anthrax
- Rabies
- Viral hemorrhagic fever

Airborne:

- Measles (Rubeola)
- Chickenpox
- TB

A new category of droplet-transmitted diseases was added.

Droplet:

- Meningitis *(Neisseria meningitidis)*
- Diphtheria
- Mumps
- Pertussis
- Plague
- Rubella
- SARS-CoV
- Novel Influenza A viruses

Federal Register, November 2, 2011[28]

The specific time frame for notification of an EMS agency is as soon as possible—no later than 48 hours after the facility suspects or diagnosis a patient that was transported with an airborne or droplet disease. The call is placed to the DICO, not to the crew that transported the patient.[27]

Note that methicillin-resistant *Staphylococcus aureus*(MRSA) and vancomycin-resistant enterococci are not listed. CDC states that they do not require post-exposure medical care.[27]

HIPAA ISSUES

With the passage of the Health Insurance Portability and Accountability Act of 1996 (HIPAA) there has been some concern on the part of medical facilities regarding the release of source patient test results to the DICO. It is not a HIPAA violation to release source patient test results in an exposure situation.

The privacy rule does not prohibit disclosure of protected health information in all circumstances. There are recognized exceptions, some of which apply to the issue of a medical facility disclosing source patient testing. A covered entity (e.g., a medical facility) is permitted to disclose protected health information without an individual's authorization to the extent such use or disclosure is required by law and the use or disclosure complies with and is limited to the relevant requirements of such law (45 CFR §164.512[a]). One of the "required-by-law" categories in the privacy rule is "Uses and Disclosures for Public Health Activities." The following use and disclosure is specifically authorized:

A covered entity may disclose protected health information for the public health activities and purposes described in this paragraph to a person who may have been exposed to a communicable disease or may otherwise be at risk of contracting or spreading the disease or condition, if the covered entity or public health authority is authorized by law to notify such person as necessary in the conduct of a public health intervention or investigation (45 CFR 164.512 [b] [1] [iv]).[29]

Medical facility IPs need to develop a working relationship with the DICOs in their community. The DICOs are available 24 hours a day, 7 days per week and should share their contact information with the IPs and vice versa to ensure timely notification.

EXPOSURE CONTROL PLANS

As with medical facilities, public safety groups must also have exposure control plans for OSHA compliance. States that are not covered by OSHA have no provision for coverage for state and local government employees. Some states such as Ohio, Georgia, and Pennsylvania have passed legislation for coverage for OSHA compliance for state and local government employees. The contents of the plan differ from that of a medical facility. To formulate a comprehensive plan, the following documents will be needed:

- The Ryan White Law- Part G
- The OSHA Regulations for Bloodborne pathogens and recordkeeping (1910.1020)
- CDC post-exposure medical follow guidelines
- The CDC TB Guidelines, which OSHA is enforcing
- The state HIV testing law
- The state medical waste regulations
- CDC guidelines for immunization and vaccination of healthcare personnel – 2011

Plans must be department specific.

Postexposure Medical Management

There are essentially three players in the notification process: the exposed employee, the DICO, and the representative from the medical facility to which the source patient was transported. The process for bloodborne pathogen exposures works differently from the process for airborne/droplet diseases.

BLOODBORNE EXPOSURE

For a bloodborne pathogen exposure, the process begins with the employee. The employee calls the DICO to report the incident. The DICO reviews the incident and makes the initial determination as to whether an exposure occurred. If the DICO determines that an exposure did occur, the DICO will contact the medical facility to which the patient was transported to request source patient testing (in accordance with state law). The source patient testing is to be in accordance with the CDC guidelines. Therefore, rapid HIV and rapid HCV testing are to be performed on the source patient. The source patient test results are then called to the DICO, and the DICO reviews them with the exposed employee. This procedure is to be timely—as soon as possible, and no longer than 48 hours. This means that the medical facility needs to expedite testing in some cases. This can be enhanced by the use of rapid testing methods. This procedure is outlined in the Ryan White Notification Law. The exposed employee does not need to have baseline testing performed at the time of the exposure. OSHA aligned with the CDC on this in 1999. The need for a baseline on the employee will be determined by the source patient test results (see Figure 54-1).

The emergency department physician makes the final determination. Unfortunately, there have been problems with incorrect exposure determinations by emergency department and occupational medicine physicians because they may have no experience or formal training with exposure determination and

post-exposure medical follow-up, especially the use of post-exposure prophylaxis.[30,31] In some cases, there may be the need for additional consultation to determine the exposure risk. The facility IP can be of great assistance in these cases. The IP can offer a second opinion in the event of a dispute between the exposed employee and the DICO or between the DICO and the emergency department physician. If there are additional differences of opinions regarding whether an exposure occurred, as stated in the Ryan White Law, the DICO can contact the public health director or the CDC to intervene. This process is also to be completed within 48 hours. If a medical facility fails to comply after public health department or CDC intervention, the U.S. Department of Justice can issue an injunction on the medical facility.[27] An injunction would halt all federal funds to the facility. It is important to note that for full coverage for exposure situations, the diseases listed in the Ryan White Act need to be blended with the OSHA bloodborne pathogens standards.

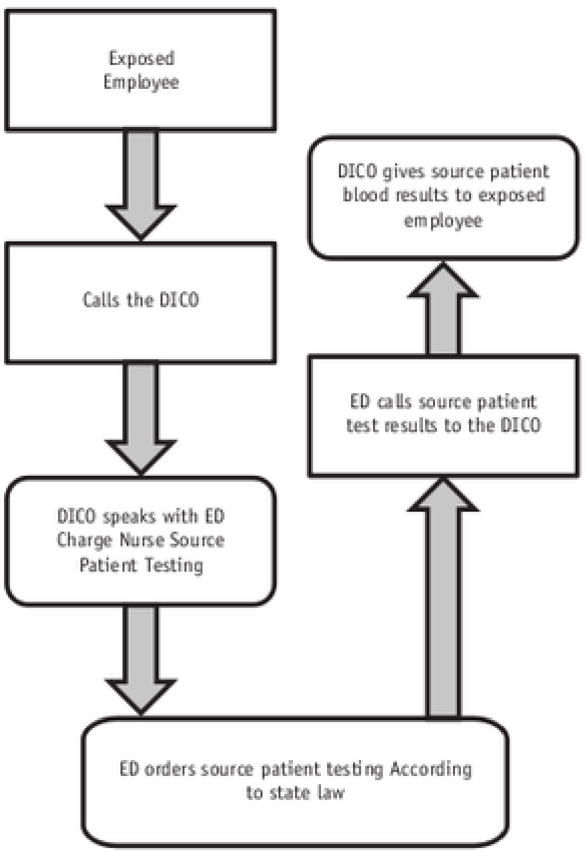


Figure 54-1.

Flow Chart Ryan White Law – Bloodborne Exposure Communication System.

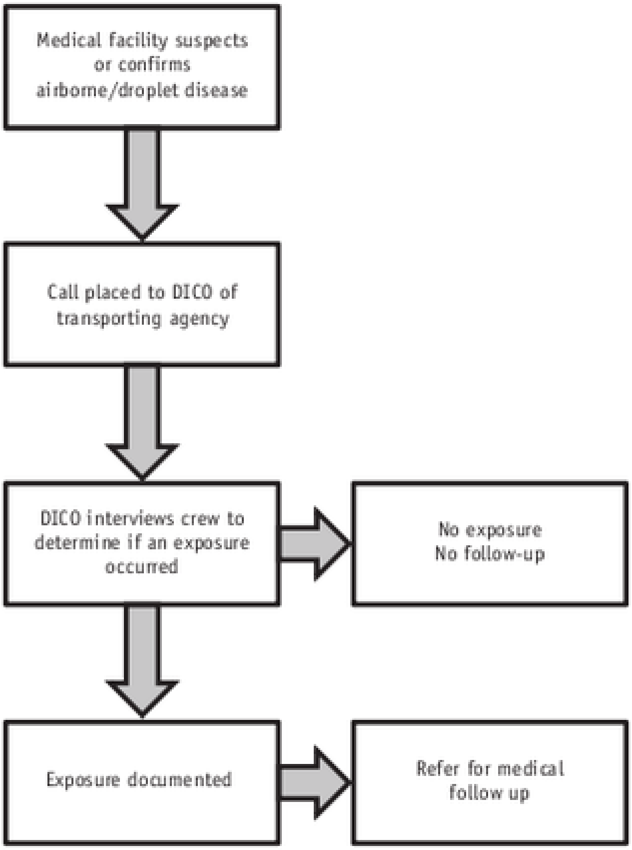
View Image

Subsequently for airborne- or droplet-transmitted diseases, the process begins with the medical facility. The medical facility (emergency department or IP) must notify the DICO as soon as possible but within 48 hours if emergency responders were in direct contact with a patient who is presumed to have or has been diagnosed with an airborne- or droplet-transmissible disease. The DICO will then interview the crew to determine whether an exposure occurred and, if so, refer the exposed department members for medical follow-up. EMS personnel may not have been aware that the patient had an airborne- or droplet-transmissible disease at the time of transport (see Figure 54-2). The emergency department or the IP should notify the DICO as soon as there is a presumptive diagnosis.[27,32] The DICO will contact the transport crew and review the care rendered and the environmental circumstances of the contact with the patient and will establish the degree of PPE that was used. If an exposure is confirmed, the exposed employees will be referred for appropriate care and treatment. The DICO should also consult dispatch records to ensure that all providers, including first responders, are notified and assessed by their respective DICOs. The responsibility for notification of the EMS transport agency is noted in the CDC's *Guidelines for prevention of transmission ofMycobacterium tuberculosisin healthcare settings*published in 2005.[32] The process is also stated in the Ryan White Notification Law Part G. Providers should display a high index of suspicion when treating patients who reside in group living settings such as halfway houses and jails, who exhibit a fever of unknown origin, cough, or a serious illness with decreased level of consciousness.

Figure 54-2.

Airborne/Droplet Communication System.

View Image



As many emergency departments in facilities today are a contracted service, the IPs assistance is necessary in ensuring that staff is trained on the proper procedures for post-exposure follow-up and applicable state law governing source patient testing. With regard to airborne/droplet diseases, the IP needs to ensure that emergency department staff is aware of their notification responsibilities and time frames for compliance. As previously stated, the EMS provider does not need to be tested or treated immediately in the emergency department following an exposure event. Source patient testing will determine the need for treatment and/or counseling. A busy emergency department is often not able to provide the time for in-depth counseling. When the source patient test results are called to the DICO, the system for medical follow-up established in the department's exposure control plan is followed. However, some state workers' compensation statutes have defined time frames for baseline testing and coverage as an on-the-job injury. OSHA clarified this in November 1999.[33] Many departments have established outside contracts for employee medical follow-up and counseling. OSHA stated that the employer "must ensure [that] proper care and counseling is offered the exposed employee." IPs should be aware of the system established by each department. Including designated officers in area meetings held by IPs is an important part of the process of information sharing between the disciplines.

Medical facilities are mandated by law to provide source patient test results in exposure incidents. Rapid testing is required for HIV and HCV under OSHA's enforcement of the CDC post-exposure guidelines. The CDC published specific HCV testing guidelines in May 2013.[34] The Ryan White Act mandates that source patient test results be provided to the DICO of the emergency response employee involved in an exposure incident. In addition, the OSHA bloodborne pathogens standard (29 CFR 1910.1030) provides that the employer of an employee involved in an exposure incident must obtain the results of the source individual's testing and make this information available to the exposed employee.[11]

The need for patient consent for source patient testing varies from state to state. Obtaining patient consent, if required, is the responsibility of the emergency department staff. Source patient testing will drive the care and counseling needs for the exposed EMS provider. OSHA defers to the state testing requirements.[11,27] The emergency department staff should request rapid HIV and rapid HCV testing of the source patient. The results should be available in less than 1 hour. HCV antigen testing should be available by the following day. If the rapid HIV test is positive, viral load testing should follow. Rapid HIV testing will eliminate the need to place an exposed EMS provider on toxic antiviral drugs while awaiting test results. If a test for HCV is positive, it must be confirmed by an HCV-RNA test.[34] Syphilis testing is also considered, based on the HIV or HCV status of the source patient. This practice is in keeping with the CDC guidelines for post-exposure management that OSHA is enforcing.[6] Source patient test results

are to be called in to the DICO. This practice is in keeping with the Ryan White Act and is not a HIPAA violation. The IP needs to ensure that the emergency department staff is educated regarding these laws, time frames, and responsibilities. This is especially important when many personnel working in the emergency departments are agency or contract staff. The Ryan White Act contains a time frame for notification of test results, which is to be as soon as possible but no longer than 48 hours.

There are situations in which the patient is not transported to the hospital. The patient may be pronounced dead on the scene or may refuse treatment and transport. However, an exposure may have taken place. The Ryan White Act addresses this issue by stating that the coroner, medical examiner, or whoever determines the cause of death is responsible for ensuring that the appropriate blood work is drawn in a post-exposure event. Many states have statutes outlining procedures for mandatory testing of persons suspected of exposing other persons to reportable diseases, including HIV.[27] The process in some states may require a signed affidavit attesting to the circumstances of the exposure. After review by the local health authority, the source patient can be traced and requested to submit to testing; there are provisions for court-ordered testing if a voluntary submission is unsuccessful. A close, cooperative working agreement with the medical examiner's office can provide the efficient completion of post-exposure testing of the deceased patient.[27]

There can be additional exposure incidents that may require special consideration and action. Some organizations maintain that personnel are available even when off duty and may experience exposures in the performance of work while in an off-duty status (e.g., a police officer who arrives at an automobile accident while not officially in an on-duty status). The major issue can be the lapse of time experienced by the provider from the exposure to actual reporting and management. Additionally, exposures can occur with materials that cannot be traced to a specific patient encounter. Materials inadvertently left in response kits, trash receptacles, and other locations may make source patient identification difficult if not impossible. Management of the exposure should focus on the mechanism of exposure and its level of risk rather than on spending an excessive amount of time determining the source patient. These exposures are handled as source unknown following the CDC flowcharts.

INFECTION PREVENTION AND CONTROL PRACTICES AND INTERVENTIONS

In the fire and EMS discipline, the infection prevention concept that has been adopted on a national basis has changed to conform to the hospital practice of Standard Precautions. The work environment of the EMS professional differs from the more controlled hospital care environment; therefore, OSHA requirements vary in some instances. OSHA and the Ryan White Law, Part G, have stated that the regulations *do* apply to volunteer services as well as paid services.[11,27] The amount of infection prevention education and training offered to personnel may vary. IPs working with department DICOs and the department's trainer may offer to assist in education and training programs; however, the IP should not undertake this task without at least a ride-along (observational) experience to be able to relate work conditions to practical infection prevention practices. Work conditions may include miscellaneous accidents, building collapses, motor vehicle collisions, and water rescues.

Although the initial focus of prehospital infection prevention has been on bloodborne pathogens and use of PPE for healthcare personnel protection, there needs to be an increased focus on protecting the patient from infection. This needs to become a key element in training and daily work practice. Training has been fear based and needs to evolve into an evidence-based model with a focus on the continuum of infection prevention beginning at the first patient encounter.

The Ambulance

The ambulance is a mobile patient care environment. It is generally divided into two spaces: the driver area and the patient care area. Patient care equipment is stored in enclosed compartments on the ambulance. Some of the equipment is wall mounted for care en route, such as suction, oxygen, blood pressure monitoring, and needle disposal containers. Stocking of supplies is done on a daily basis. Some medical facilities stock EMS drug boxes and conduct equipment exchanges in the emergency department. IPs should know whether this practice is undertaken in their facilities. Organizations should research the availability or feasibility of injury protection devices for instruments that currently are not equipped with such devices and conduct appropriate evaluations and/or field tests to ensure that the devices will not adversely impact the delivery of patient care or result in providers delaying treatment or attempting to circumvent the intended functioning of the safety device. Additionally, efforts should be made to determine the system clinical operating guideline and educational requirements necessary for the integration of such devices into the patient care system. This activity should be listed in the exposure control plan.

Air circulation in the vehicle is generally rapid, low-velocity airflow. Some ventilation systems fully exchange patient care air space in 1 to 2 minutes. This may vary among manufacturers. Some vehicles have ventilation systems with high-efficiency particulate air (HEPA) filters, which need to be changed every 6 months. There is also an exhaust fan to assist in air exchange. These air handling systems are the reason the CDC 2005 TB guidelines indicate TB being a low risk for EMS providers.[32]The floor and walls are constructed for ease of cleaning.

EN ROUTE COMMUNICATION

As part of the initial response protocol, most communication dispatch centers will provide basic incident information to the responding units. Because the general public can monitor the emergency communication frequencies, such information is devoid of personal and pertinent identifying information. Systems that use a computer-aided dispatch or mobile data computer technology can forward a text message informing the crew of additional significant information. The transmission of specific disease information about a patient does not enhance patient care. All providers are instructed to use Standard Precautions; this includes treating all patients and body fluids as potentially infectious. Thus, any communication that places the onus on the patient to report the presence of a disease abdicates the responsibility of response personnel to initiate proper Standard Precautions. Agencies are strongly discouraged from entering disease information into premise history or patient history files because such information can become outdated very rapidly. However, for airborne- or droplet-transmitted diseases, information may be shared, as the use of a surgical mask on the patient is not part of Standard Precautions. This is a public health issue, and the rules differ from those for bloodborne diseases.

EMS personnel should provide the receiving medical facility with basic information about the imminent arrival of the patient. In addition, there may be a request for additional interventions beyond the scope of the clinical operating guidelines that have been developed and reviewed by the medical facility, the physician medical director for the EMS services, and EMS personnel. Communications are not limited by HIPAA because the transmission of information is required to obtain orders to provide treatment. This is addressed in the discussion of the minimum necessary rule of the HIPAA regulation. However, only the information necessary for the provision of direct patient care based on presenting signs and symptoms is appropriate. Communication over open airwaves should not cite that the patient is HIV positive or HCV positive, because this information would not be needed during the transport phase.[35]Information suggestive of an airborne/droplet disease may be transmitted.

EMS personnel will give the emergency department a patient history, physical assessment, vital signs, medication listing, and all elements of care provided during transport.

IN-FIELD CARE

In fire and EMS, care is frequently provided in the outdoors and in all types of weather and circumstances. Such conditions may increase the risk for patient infection because of wound contamination or equipment contamination at the location.

Most emergency equipment is carried to the site of treatment. Equipment may be carried in either soft-sided bags or hard plastic tackle-type boxes. Equipment may include the following:

- Needle safety devices, which may include standard intravenous (IV) catheters, intraosseous infusion needles, needles, and syringes
- Glucometers
- Obstetrical pack
- Suction
- Bandages, dressings, and splints
- Pharmaceuticals
- Airway management equipment
- PPE
- Portable oxygen delivery and ventilation assist equipment
- Nebulizer kit
- Cardiac equipment (AED and monitor/pacer)
- Intravenous and irrigation fluid supplies[2]

Due to the environment in which care must be rendered, IV starts and wound care may be undertaken in less-than-ideal (aseptic) conditions. Although every attempt should be made to properly prepare the insertion site, time and environment may preclude this from happening. Field personnel should be instructed to communicate to the emergency department when the circumstances of IV access have been particularly difficult. Generally, IV lines and dressings placed in the field are removed in the emergency department or should be replaced within 24 hours. Emergency department staff should carefully assess each patient for wound contamination (i.e., oil, chemicals, debris) in all patients transported from an accident scene.

The need to provide periodic or continuous boluses of medications may require providers to consider an exemption from the "no recapping policy" when introducing medications intravenously. The nature of the work environment may not permit the medication apparatus to remain in the access port. EMS agencies should monitor new products that will negate the need for an exemption.

Endotracheal tubes and laryngoscopes are used under difficult conditions in most cases. Blades and scopes are stored in a variety of ways. Whatever method that is used for the storage and carrying of the equipment; it should be such as to minimize potential contamination and the compromise of its aseptic field. If nondisposable blades are used, they are to be cleaned using high-level disinfection (see **31. Cleaning, Disinfection, and Sterilization**). In some locations, departments are now using desktop autoclaves for the reprocessing of items that require high-level disinfection.

The increased shortage of certain emergency medications has resulted in many services initiating the use of compound pharmacies to meet patient care needs. Many of these compounded medications are not packaged for multiple patient usage and hence do not contain appropriate preservatives. Attention to safe injection practices becomes essential to prevent possible contamination and transmission of pathogenic organisms. Each dose should be considered single-patient use and there should be a new needle and syringe for every injection. Special attention should be given during events where multiple patients may be receiving similar medication regimes. There should be no attempt at consolidating remaining doses. See the CDC's Safe Injection Practices One and Only Campaign materials for more information.

Providers should consider newer airway management equipment and procedures that can reduce the complications of infections seen as a result of airway management. Among the considerations is the use of noninvasive ventilators such as continuous positive airway pressure (CPAP) devices. The implementation of CPAP has been documented to reduce the need for endotracheal intubation and thus decrease the episodes of ventilator-associated pneumonias.[36]

USE OF PERSONAL PROTECTIVE EQUIPMENT

Gloves

Gloves should be worn when it can be reasonably anticipated that an employee will have hand contact with blood or other potentially infectious material, mucous membranes, and nonintact skin; when performing patient care procedures; or when handling or touching contaminated items or surfaces.

In an effort to comply with the NIOSH alert (June 1997),[37]departments and agencies are moving away from the use of powdered latex or powder-free latex gloves and toward the use of vinyl, nitrile, or new composite glove materials as much as possible. When latex is needed, low-protein, powder-free gloves should be used. Disposable gloves should be replaced as soon as practical when they become contaminated, torn, or ripped. Disposable gloves should not be washed for reuse. Following glove removal, hands should be decontaminated with alcohol-based hand gel or towelettes while on scene.

Heavy-duty utility gloves (dishwashing style) should be used when cleaning contaminated equipment or surfaces or when disposable gloves are insufficient.[38]Heavy-duty utility gloves can be washed and reused as long as they are not torn or cracked. Leather gloves are to be worn for extrication and urban search activities.

Masks

Masks should be worn when there is suspicion that a patient may have an airborne- or droplet-transmissible disease. The basic rule is "fever and a rash, use a mask." Every effort should be made to contain aerosolized particles exhaled from patients. The style of mask issued is usually the molded fitted surgical type. If the patient is suspected of having or is diagnosed with TB, a surgical mask should be placed on the patient to contain secretions. Patients exhibiting acute respiratory distress should be administered oxygen via a nonrebreather facemask. For those who are not in severe distress, a surgical mask may be placed on the patient. In September 2010, the CDC removed the requirement of respirators for prehospital care.[39]However, in the state of California, CAL/OSHA passed a more restrictive regulation for the use of a P100 respirator for all droplet-transmitted diseases. It should be noted that fit testing is required for the use of respirators (N95, P100). If respirators are to be used, there must be full compliance with the OSHA 1910.134 Respiratory Protection Standard.[40]It should be

noted that this regulation is not supported by science. This offers an example of the importance of evidence-based practice.

Eyewear

Protective eyewear in conjunction with masks must be used when it is reasonably anticipated that there may be the opportunity for gross splatter of blood or other potentially infectious material into the eyes, nose, or mouth. Such splattering should be considered any time a patient is prone or unconscious or when there is visible blood evident. Mucous membrane protection may be afforded by using the combination eye shield and surgical mask apparatus or a respirator mask and approved eyewear. Providers should use full respiratory protection (i.e., surgical or procedural mask, eye protection, and gloves) when examining or treating potentially high-risk respiratory patients. All three items must be worn as an ensemble to qualify as full respiratory protection.

Face shields on rescue helmets should not be used routinely for infection prevention purposes because they do not protect against materials that splash up underneath the face shield. OSHA's Compliance Directive (CPL 02-02-069)[41]states that prescription glasses with side shields may be worn.[26]EMS providers requiring remedial eyewear should be provided eyewear that will adequately cover their glasses and prevent penetration of fluids.

Protective Clothing

Appropriate protective clothing, such as cover gowns, aprons, or similar outerwear should be worn in exposure situations. Disease may be transmitted when the provider has direct contact with a patient or environmental surfaces that are contaminated. Providers should be attentive to rashes, ulcerations, weeping wounds, and patients incontinent of urine and feces. When responding to healthcare and long-term care facilities, providers should be attentive for signage that stipulates isolation precautions are in effect. This should not be relied upon, however: many long-term care facilities do not isolate due to the mobility of patients.

In other patient contact scenarios, the type of protective clothing to be used will be based on the anticipated exposure. Turnout gear also protects clothing from splashes and is preferable in fire, rescue, or vehicle extrication circumstances and should always be worn when on such scenes. In some cases, station uniforms will serve as PPE.

Given the increase in new and emerging diseases, the transfer of patients under some level of infectious disease precaution can be expected to increase. The recent interim guidelines for Middle East respiratory syndrome **coronavirus**(MERS-CoV) require patients to be placed in an airborne infection isolation room (AIIR). If an AIIR is not available, the patient should be transferred as soon as is feasible to a facility where an AIIR is available.[42]This applies to the medical facility. However, clarification from the CDC states that a surgical mask is all that is needed in EMS.

EMS providers should have interfacility transfer procedures that**establish practical and effective measures for isolating the disease organism, not the patient.** Such procedures should follow those outlined in *Guidelines for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings*.[43]

Pocket Masks

All personnel trained in the administration of cardiopulmonary resuscitation (CPR) must be trained in the use of either a latex free bag valve mask device or a pocket mask. All personnel should be trained in

the proper use of the pocket mask and the method for proper disposal or cleaning (see Table 54-2).

Table 54-2 Guide to Use of Personal Protective Equipment

Task	Gloves	Eyewear/Mask	Gown
Airway	X	X	Available
CPR	X	None	None
Drawing blood	X	None	None
Decontaminate equipment	Utility	If splatter or splash anticipated	If splatter or splash anticipated
Extrication	X	If splatter or splash anticipated	If splatter or splash anticipated
Field delivery (child birth)	X	X	If splatter or splash anticipated
Injection	None	None	None
Intubation	X	X	Available
Intravenous start	X	If splatter or splash anticipated	Available
Monitor	None	None	None
Oxygen	None	None	None
Suction	X	X	Available
Trauma	X	X	X
Vital signs	None	None	None

*Based upon the CDC Guidelines for Public Safety Workers.**10**

Alternatives

Because of the difficult situations that EMS responders may encounter, the use of PPE may not always be feasible or possible. This situation is addressed in the OSHA *bloodborne pathogen rule*under the section on PPE. The compliance directive to this regulation gives clear examples of when PPE use may not be feasible in the provision of EMS care (i.e., latex-free bag valve mask device does not work or was lost in response).44

MULTIPATIENT OR MASS CASUALTY INCIDENTS

When faced with a multipatient or mass casualty incident, providers should attempt to adhere to the basic principles of infection prevention: prevent contamination and exposure of the provider to the body fluids of the patient(s) and prevent cross-contamination and exposure to other patients.

Under normal operating conditions, providers should change gloves between each patient. Unfortunately, during an emergent situation, supplies may be severely limited during the initial stages of the response. It is incumbent on providers to consider *not*changing gloves between patients unless there are gross,

liquefied bodily fluids evident on their gloves as they move to the next patient. Remember this in a mass casualty event: "The greatest good for the greatest number."

During training for such events, infection prevention considerations should stress steps that providers can implement to deal with the need to rapidly change gloves, as follows:

- Place additional spare gloves in a fanny pack or pants pockets.
- Make sure that any open areas on hands or arms are covered with an occlusive dressing.
- Apply three or four pairs of gloves and use a shedding process of removing the top layer as it becomes overly soiled with liquefied body fluids or the structural integrity of the glove(s) is compromised.
- Use 4x4-in. gauze to wipe the accumulated fluid from the glove(s) to decrease cross-contamination to the next patient.

If providers expend their personal inventory of gloves, they should continue the assessment or treatment of patients until their gloves are overly soiled or torn and then should remove themselves from patient contact responsibilities. Given the potential intensity of contact with bodily fluids, hand hygiene should be undertaken at the earliest time using non-water-based materials such as alcohol hand sanitizer or towelettes.

POSTRESPONSE CLEANING

At the conclusion of the on-scene operations, all potentially contaminated patient care equipment should be removed, cleaned, and decontaminated for reuse unless its removal will hamper an ongoing criminal investigation.

Focus should be on high-touch areas—what care providers used to care for the patient, patient contact areas, and equipment used for patient care.

There are three distinct levels of patient care equipment, each of which requires a different level of cleaning/decontamination:

- Noncritical equipment: stethoscopes and blood pressure cuffs. This level of equipment requires cleaning.
- Semicritical equipment: stretchers, vehicle walls and floors, communication headsets, defibrillator. This level of equipment requires disinfection.
- Critical equipment: resuscitation equipment or intubation equipment. This level of equipment requires sterilization or high-level disinfection.[10]

Special attention should be provided for medical equipment that has demonstrated direct contact with source patient blood such as glucometers. Although the need for such cleaning is obvious in the presence of visible blood, if no visible organic material is present, the exterior surface of devices should be disinfected after each use following the manufacturer's directions using a cloth/wipe with either an EPA-registered detergent/germicide with a tuberculocidal or HBV/HIV label claim, or a 1:100 concentration of bleach is recommended for use in EMS.

MEDICAL WASTE

Although any item that has had contact with blood, exudates, or secretions may be potentially infective, it is not normally considered practical or necessary to treat all such waste as infective. In 1985, the

CDC published the following statement:

There is no epidemiological evidence to suggest that most hospital waste is any more infectious than residential waste. Moreover, there is no epidemiological evidence that hospital waste disposal practices have caused disease in the community; therefore, identifying waste for which special precautions are indicated is largely a matter of judgment about relative risks of disease transmission.[30,45]

Each state has specific regulations and definitions that address what constitutes medical waste. These laws apply to medical facilities as well as EMS. Generally, unless grossly contaminated with nondried blood, such articles can be disposed of in the regular waste management system. OSHA defers to each state's regulation.[11]

EMS field personnel should consider any materials that contain cultures and stocks of infectious agents and associated microbiologicals, pathological waste (e.g., human tissues, organs, and body parts), nondried blood and blood products, sharps, and animal waste to be infected medical waste. Such waste should be placed in biological hazard bags and sealed. The sealed bag should then be delivered to a predetermined location for proper removal and disposal. It is helpful when medical facilities accept this waste. Sharps are always to be considered regulated medical waste. It may be difficult for EMS agencies, especially volunteer agencies, to contract with a waste company since the volume of biological medical waste they generate is very small. Therefore, it is helpful if local medical facilities accepted this waste. It is important to review state medical waste definitions for clarification.

Cleaning and disinfection procedures require the total removal of organic material prior to applying a disinfectant (see **31. Cleaning, Disinfection, and Sterilization**). Cleaning may be completed using standard soap-based cleaning solutions. Disinfection should be performed with an EPA-approved disinfectant or a bleach/water solution of 1:100.[10]Due to the delicacy of some patient care equipment, the use of alternative disinfecting solutions may need to be explored, based on the manufacturers' recommendations so as not to void a warranty or damage the equipment. The use of bleach/water solution is important following care of patients with *Clostridium difficile*or norovirus. Some departments use hospital-grade products. Initial cleaning should be performed at the medical facility and before another call. Emergency departments may make cleaning products available.

Some incidents may not result in the transport of a patient to a medical facility. Providers should understand the procedures to properly contain any patient care equipment that requires cleaning and disinfection. The use of alcohol-based hand-washing solutions must be made available to ensure proper hand hygiene on scenes at which water is not readily available. At the station, equipment cleaning may be performed in the vehicle bay area. If this area is used, it should be equipped with floor drains and be well ventilated. Newer facilities may be equipped with cleaning and decontamination rooms that allow adequate cleaning of equipment and that are designed to prevent cross-contamination. These facilities are also properly vented to the outside (Table 54-3).

Some EMS agencies have initiated the use of disinfection fogging apparatus. These products produce an atomized fog that can permeate throughout the vehicle and provide terminal disinfection. Agencies are advised to ensure the application of such products will be done in a manner and timeframe that prevents the inadvertent exposure of providers and patients to any residual vapors or materials. Additionally, such fogging should not supplant normal cleaning schedules and requirements.

Table 54-3 Guide to the Care of Specific Contaminated Equipment

Item	Procedure

Airway	1
Backboards	2 (3 if grossly contaminated)
Blood pressure cuffs	2, 3, 5
Bulb syringe	1
Cervical collars	1 or 2 (if gross contamination)
Dressings/paper products	1
Drug boxes	2, 3
Electronic equipment	Check manufacturers' recommendations
KED (Extrication device)	2 or 3 (same as backboards)
Laryngoscope blades	4 or 1
Linens	1 or 5
Needles/syringes	1
Oxygen	1
Cannulas/masks	1
Humidifiers	1 or 2
Penlights	2
Pocket masks	1 or 3
Restraints	2
Bag-mask device	1 or 4
Scissors	2 or 3
Splints	2
Stethoscope	2 (3 if grossly contaminated, wipe with alcohol)
Stretcher	2 or 3
Stylets	1 or 4
Suction catheters	1
Suction canisters	1 or 4
Uniforms	5

1, dispose; 2, cleaning (soap and water); 3, disinfection (bleach/water @ 1:100 or other EPA-registered disinfectant); 4, high-level disinfection (Cidex OPA); 5, launder.

Cleaning of Equipment Left at the Hospital with the Patient

When EMS leaves a patient at the medical facility with emergency equipment still in place (e.g., backboard, cervical collar), the hospital must either clean the equipment or "red-bag"[31] it (i.e., identify it as infectious waste) for department members to transport it safely to be cleaned at the station.[44] At times, equipment is cleaned in the ambulance bay at the hospital to prevent the transport of contaminated equipment and the possible contamination of the ambulance.

OTHER PUBLIC SAFETY CONCERNS

Although law enforcement personnel can be involved in initial patient care, most of the potential disease threat may occur during direct contact with individuals while restraining them for arrest or searching them or their vehicles for evidence or contraband. Such direct contact may result in potential exposure to open sores and lesions that may harbor resistant organisms. Additionally, individuals may have underlying respiratory infections such as TB that may expose the transporting officer. Law enforcement agencies should encourage the use of surgical masks for individuals who are in custody and being transported in confined spaces and exhibit any coughing or sneezing. Further, there are individuals involved in the collection and inventory of property and evidence (evidence technicians and crime scene investigators) who may have contact with biological hazards. In addition, the prolonged need for storage of such materials during the investigative and trial components can result in the proliferation of various fungi and other organisms in the environment of the evidence area. The need for proper ventilation and humidity control becomes very important not only to preserve the evidence but also to ensure a safe and healthy work environment for inventory management personnel. Law enforcement agencies need to work with medical facilities or participate in existing governmental contracts for the prompt and safe disposal of sharps no longer needed as evidence. Training and education of law enforcement in the arena of infectious diseases requires refinement and adaptation. This continues to be an evolving field within public safety.

CORRECTIONAL OFFICERS

Personnel dealing with inmates in correctional facilities also face infection and disease issues with large populations in overcrowded conditions. Correctional personnel should work with the medical personnel of facilities to ensure that there is consistency and familiarity in dealing with any infectious disease issues when they occur (see **51. Correctional Facilities**).

IDENTIFY NEW ROLES

Expanding the scope of job responsibilities of public safety personnel into health promotion further increases the melding of prehospital care and infection prevention. In an effort to ensure that children are properly immunized for school and that adults are protected against influenza, EMS personnel (paramedics) and firefighters are being enlisted in some states to provide childhood immunizations.[46,47]

This ability depends on the scope of practice for EMS providers in each state. Such effort may be expanded to meet the community needs in the event of a large-scale outbreak such as a pandemic. This took place in 2009 with the H1N1 pandemic. The education provided not only teaches new skills but also reinforces the benefits immunizations play in disease prevention and increases the overall health of the community. Certainly, the reinforcement of the principles for proper patient preparation and disposal of needles and syringes is paramount in the development and implementation of such a program. Expansion of paramedic scope of practice and adding vaccines to the EMS drug formulary in some states, such as Virginia and Texas, has enabled departments to administer their own vaccines and immunizations to department members. This effort can increase member participation and lower costs.

As the healthcare industry continues to identify new ways to more effectively manage the utilization of healthcare, there has been the recognition for the case management of certain patients that have perceived increased need of services through the emergency department. Such case management has seen the rise of community paramedics within EMS. Community paramedics work in conjunction with healthcare providers, hospitals, social service agencies, and patients to develop a long-term treatment plan to address the underlying concerns of the patient while decreasing the use of expensive and timely services of the emergency department. Although the primary infection prevention issues are not significantly different, evaluation of patient interaction scenarios may require attention to issues usually seen in the home healthcare setting, and such providers should make the appropriate adjustments to ensure that they are adequately addressed.

COMMUNAL LIVING

Within the fire and EMS station environment, there is increased attention to the general sanitation of the community living conditions. Increased attention to food safety and an emphasis on the need for maintaining proper temperatures of potentially hazardous foods are the latest efforts at increasing employee health and well-being. Ensuring that temperatures are monitored and maintained has become a new responsibility for company officers. The issues of station living have become increasingly important, as the issues of lice infestation and MRSA infection come to the forefront. Cleaning of exercise equipment is also important. Shared sleeping and recreational areas may provide the opportunity for inadvertent exposure to occur. Attention to compliance with the CDC work restriction guidelines updated in November 2011 will ensure that no response team members are inadvertently exposed. Additionally, the benefits of an employee absenteeism tracking system to detect subtle variances in sick call associated with specific stations, shifts, or other criteria can serve as an early sentinel to possible infectious disease implications among response personnel. Planning and education have been cornerstones in guaranteeing the safety of employees, coworkers, and patients in implementing a pre-event inoculation program.[47]

BIOTERRORISM

Compounding the usual infection prevention issues, the addition of bioterrorism has many responders recognizing the role they play as the early warning sentinels for identifying potential outbreaks. By raising the index of suspicion as early into the contact with a patient as possible and recognizing an increased number of patients of a similar response type, prompt community efforts at containment and isolation can begin. Although it is certainly not the responsibility of emergency healthcare personnel to identify or diagnose an infectious disease, patient medical history, especially relating to travel, the application of PPE, proper patient packaging, and early facility notification can result in fewer additional exposed or infected patients and healthcare personnel. With the advent of new and emerging diseases, the use of such procedures on a more regular basis can provide the opportunity for consistency and familiarity if a biological terrorism attack or pandemic occurs (see **120. Infectious Disease Disasters: Bioterrorism, Emerging Infections, and Pandemics**). The federal government continues to provide opportunities for education and training programs for the assessment and transport of patients who may have biological agent illnesses.

The increased number of responses to packages containing anthrax during the autumn of 2001 required a re-examination of response resources. Initially, departments saw responses to such threats and concerns as typical hazardous materials emergencies. It quickly became evident that maintaining the usual resource deployment to such responses used large amounts of response assets, diverting them from other emergency activities. The incidents further required a coordinated response with emergency responders, hospitals, local health department personnel, and state health laboratory technicians.

Coordination focused on tracking samples, identifying potential patients, and rapidly notifying testing results. Various types of drills are being conducted across the country to assess response readiness. Sharing of after-action reports on these drills needs to be actively reported to all disciplines for a true identification of areas for improvement to occur. This is also the case with pandemic drills. It is important to recognize that incubation periods play an important role in bioterrorism response situations and drills.

Many EMS personnel may be trained to assess patients for signs and symptoms of biological agent illnesses. In a biological agent dispersion situation, most cases will not be identified for several days. Today, calling 9-1-1 (or 9-9-9 in Great Britain) for an ambulance for transport is the norm. For this reason, EMS will play a key role in the initial identification and transport of these patients. Public safety agencies should be involved in a comprehensive community surveillance program. Agencies should participate in their state public health information network. Such a network can provide early notification of evolving public health threats and conditions. Surveillance monitors, including the over-the-counter sale of common symptom treatments, can alert a community to some underlying malady. The use of automated syndromic surveillance software that alerts providers to the attainment of threshold alarm levels of certain syndromes can provide the necessary trigger for a more thorough investigation to be undertaken. Finally, the use of human intelligence, which increases concerns not just for reportable diseases but anything strange or out of the norm, should be shared with other community partners.

Intelligence gathering of world health issues can assist in the initiation of the monitoring of people coming and going to suspected or known disease "hot spot" areas. Individuals attending conventions or music festivals and those who have business travels overseas can serve as harbingers of emerging disease outbreaks. If a disease becomes widespread in the community, public safety agencies may need to assist with the implementation of the appropriate control measures of restriction, isolation, detention, or quarantine.

Additionally, agencies should plan to maintain a large-volume contingency inventory of PPE. The use of such PPE should be appropriate for conditions of the disease. It is important to ensure that PPE is used appropriately for patient conditions that present during the provision of care. Indiscriminate use of PPE could result in the rapid reduction in available inventories and, with increased worldwide utilization, could prevent adequate restocking of necessary inventories from vendors. Given that providers may encounter new or emerging strains of organisms, the development and delivery of "just-in-time" educational programs may be necessary. The curriculum should include components that cover disease recognition, notification procedures, PPE donning and doffing, transport considerations, cleaning and disinfection, and post-exposure follow-up.

Usually EMS interactions are single-patient contact events. Providers must have a heightened level of suspicion to the signs and symptoms of communicable diseases, particularly when others present with similar symptoms within the same household, facility, or part of a facility. Mechanisms should be developed to ensure that information is shared with the transporting unit, the receiving medical facility, and the appropriate health department.

Education should focus on obtaining a good patient history, including travel history, and assessment. Emphasis on the six CDC Category A biological agents and their presenting signs, symptoms, and prodromes will be vital in raising the level of wariness. The criticality of vital signs with special weight on obtaining a temperature should be explicitly detailed to providers. The patient should be "wrapped" and a surgical mask applied before the patient is moved if there is suspicion of weeping lesions or other exudative material.

As indicated earlier, agencies may want to explore and expand considerations in the use of CPAP devices. Given the expected high demand for yet a small national inventory of ventilators, a study involving the use of noninvasive ventilators during the 2010–2011 H1N1 influenza outbreak demonstrated a decrease in the number of patients requiring endotracheal intubation and thus reduced the episodes of ventilator-associated pneumonias and death.[48]

Contact should be made with the receiving facility to outline the receipt of the patient and the concerns that raise the suspicion. On arrival at the medical facility, the EMS providers should disembark the patient only when it is clear where the patient will be taken.

The IP should assist public safety agencies to anticipate illness events that may occur within the community. Agencies should be educated to understand the organizational implications of such illness events. This includes the possible continued community contact with individuals who are or believe they are infected with the disease. Such events can disrupt the normal community living arrangements of the unit station. Ultimately, emergency responses may be hampered as a result of personnel shortages or other response resource shortages or issues.

TRANSPORTATION/CLEANING REQUIREMENTS FOR BIOLOGICAL AGENTS

EMS training also should address appropriate use of PPE and cleaning routines. The following information can serve as a guide for the DICO and the IP to facilitate proper care and reduce the incidence for exposures.

It should be noted that for most biological agent illnesses, no special precautions or cleaning procedures are indicated. Each department or agency will need to review the importance of following the routine use of PPE based on patient presenting signs or symptoms and compliance with routine cleaning after transport.[49,50]

ROUTINE VACCINATION AND IMMUNIZATION FOR FIRE AND EMERGENCY MEDICAL SERVICES PERSONNEL

The recommended vaccines and immunizations for fire and EMS personnel follow the same CDC recommendations for all members of the healthcare team. The listing is also reflected in the NFPA 1581 Infection Control Standard. Included are HBV vaccine; Td (tetanus and diphtheria) or Tdap (tetanus, diphtheria, and pertussis); measles, mumps, rubella (MMR) vaccine if not immune; varicella vaccine if not immune; and annual influenza vaccine. TB skin testing should be undertaken at hire and as needed, based on the TB risk assessment for department transports. TB risk assessment for fire and EMS personnel is based on the number of active, untreated TB patients transport in the previous year.[15,51,52]

Declination forms are to be signed if a provider chooses not to participate. Declination forms are required under NFPA 1581, CDC guidelines, and OSHA. Declination forms serve to document that the employer met their obligation to offer the needed vaccines/immunizations. With the push for some vaccines to be mandated for healthcare providers, this should extend to the fire/EMS community as well. This will become more important as practice expands into community medicine.

Disaster Response

Earthquakes, floods, and tornadoes have resulted in EMS personnel responding in large numbers to areas that have been affected by such incidents. There have been many questions regarding which vaccines and immunizations are needed for personnel responding to these situations. On September 1,

2008, the CDC published immunizations recommendations for disaster responders. The recommendations are as follows:

1. Tetanus: In accordance with the current CDC guidelines, responders should receive a tetanus booster if they have not been vaccinated for tetanus during the past 10 years. Td (tetanus and diphtheria) or Tdap (tetanus, diphtheria, and pertussis) can be used; getting the Tdap formula for one tetanus booster during adulthood is recommended to maintain protection against pertussis.
2. Hepatitis B: HBV vaccine series for persons who will be performing direct patient care or are otherwise expected to have contact with bodily fluids.

There is **no**indication for the following vaccines for disaster responders in the United States:

- Hepatitis A vaccine (low probability of exposure): vaccine will take at least 1 to 2 weeks to provide substantial immunity.
- Typhoid vaccine (low probability of exposure)
- Cholera vaccine (low probability of exposure, no licensed cholera vaccine available in the United States)
- Meningococcal vaccine (no expectation of increased risk of meningococcal disease among emergency responders)
- Rabies vaccine series (the full series is required for protection). Persons who are exposed to potentially rabid animals should be evaluated and receive standard post-exposure prophylaxis, as clinically appropriate.[52]

Surveillance within the EMS Department

As the CDC highlights the continuing emergence of new organisms—some that are becoming ever resistant to our currently available antibiotic therapy arsenal—prehospital providers must remain aware that as our cities become more international, these organisms are provided access into communities via educational, business, and entertainment sectors, as well as citizens that avail themselves of the myriad travel opportunities to many far off locales.

Fortunately, even with the emergence of these new threats, the current isolation precautions outlined in this text are effective in providing protection to patients, providers, and the community. These precautions offer practical and effective measures for isolating the disease organism whatever it is. Given that many illnesses present with the same signs and symptoms, it is important to continue to follow the organizational infectious disease plan even when the underlying disease organism is unknown. If there is an occasion for changes in the precautions, prompt notification should be distributed to agency providers.

Conclusions

During these uncertain and changing times, it is important that the IP share information and bulletins produced by CDC, state, and local health departments regarding diseases or infection prevention changes. The IP needs to share this information with the DICOs in the area to ensure that all involved are up-to-date on current information. Creating a network for information sharing via email or fax is part of a complete information sharing and communication system.

Future Trends

Beginning with the events of September 11, 2001, and including the SARS global epidemic, avian influenza, and novel H1N1 threats, the need for seamless healthcare delivery has become increasingly important. Specific needs, such as standardization of language across fire, police, EMS, and public safety, must be addressed across disciplines as well as across borders. The integration of the concepts of the national incident management systems and hospital incident command system (HICS) can provide the opportunity for communication clarity during community-wide emergency events. Clear definitions of care practices, such as Standard Precautions, use of PPE, and initiation of isolation precautions, also must occur. Further standardization of applications is needed, as is the inclusion of these changes in various educational curricula. Ideally, these changes should be under development now so implementation can be done outside the chaos of crisis. Such broad-sweeping changes across disciplines will require new levels of collaboration and negotiation. If successful, all populations will benefit.

EMS providers should work to expand the concept of infection prevention as a continuum and ensure that EMS processes and procedures become proactive in preventing or reducing the effects of health care associated infections such as:

- Ventilator-associated pneumonias
- Catheter-associated bloodstream infections
- Wound management
- Environmental cleaning and sampling

International Perspective

The structure of EMS delivery in the international arena is difficult to ascertain. Information on the Canadian system indicates a structure similar to that found in many areas of the United States. Most of the delivery of EMS in Canada is through regional and providential organizations. The level of training and education of the providers is that of a paramedic. As within the United States, occupational exposures in a prehospital environment are a frequent occurrence.

An act that amended Canada's Health Protection and Promotion Act, Bill 105, requires the taking of blood samples to protect victims of crime, emergency service workers, Good Samaritans, and others. The bill was given royal assent on December 14, 2001, and came into force on September 1, 2003. There are provisions contained within the Ontario Health Protection and Promotion Act that outline the process for obtaining source patient blood.[53]

Following the SARS epidemic, the Canadian emergency response system experienced a spectrum of difficulties from care provision to communication. These experiences have resulted in a greater understanding of the need for standardization in communication between healthcare disciplines as well as standardization in healthcare practices. As the lessons learned from these colleagues continue to be defined and documented, changes in traditional healthcare, as well as within emergency response disciplines, can be expected to follow.

In 2012, the United Arab Emirates (UAE) began a full review and training program to incorporate infection prevention efforts in a uniform manner throughout the UAE. Hopefully this will expand to other areas of the Middle East.

Interest for improved infection prevention within EMS has been explored in South Africa and South Korea. Specific emphasis has been on the recognition of the role EMS has in preventing disease progression and the need for consistent standards of infection prevention that are countrywide.[7]

Supplemental Resources

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Endoscopy

Author(s): Michelle Day, MSN, BSN, RN, CGRN
Team Leader Comprehensive Liver Center

Hartford Hospital
Hartford, CT

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Abstract

Flexible endoscopy has become an invaluable diagnostic and therapeutic tool. As with all diagnostic and therapeutic procedures, there are always risks of complications, including infections. To minimize the risk of infection, healthcare personnel must ensure that equipment is designed and maintained properly and that guidelines for reprocessing are strictly followed.

Key Concepts

- Flexible endoscopy is an invaluable diagnostic and therapeutic tool.
- Infectious disease outbreaks associated with endoscopic equipment, accessories, and automated endoscope reprocessors have been documented, despite strict adherence to reprocessing procedures.
- Meticulous cleaning followed by disinfection and/or sterilization is critical to ensure prevention of patient exposure to infectious diseases and thus ensure patient safety.
- Healthcare personnel (HCP) responsible for reprocessing endoscopic equipment should receive education and demonstrate competency prior to assuming responsibility for cleaning, disinfection, and/or sterilization. Education should be ongoing and competencies should be validated on a routine basis. Policies should cover the frequency and methods for validation and record-keeping and be rechecked on a routine basis. These fundamentals are integrated into the quality assurance program.
- Facilities should have clear policies and procedures for response to reprocessing errors and failure in infection prevention related to cleaning and disinfection/sterilization of endoscopes.

Background

Endoscopes, devices used to visualize the interior of a hollow organ or body space, have been used since the 1800s. During this early period, rigid tubes containing a series of lenses and mirrors were inserted into natural body openings and the images were transmitted using natural light. The neo-endoscopic era began in the 1950s with the introduction and application of fiber optics—the transmission of images and light along flexible bundles of coated glass or plastic fibers. This technology allowed the development of flexible instruments capable of internal visualization of the gastrointestinal (GI) tract, respiratory tract, and ultimately, all hollow organs and body spaces. Significant advances in endoscopic devices provide imaging technologies

capable of transmitting clear, video images through which practitioners can perform therapeutic and surgical procedures. [1]

These devices and procedures have substantially reduced the risks associated with open surgical procedures and general anesthesia, minimized the recovery period for patients, and reduced healthcare costs. However, these procedures are not free of surgical or infectious complications. Patients may develop infections from their own endogenous flora as the instruments are passed through the gastrointestinal, respiratory, or urinary tract or from exogenous sources associated with contaminated or inadequately reprocessed equipment or supplies.

The inherent complexity of the instruments with their long, narrow lumens, flexible joints, multiple channels, openings, and valves poses significant reprocessing challenges. Reprocessing requires meticulous cleaning and high-level disinfection or sterilization of internal channels, external surfaces, openings (ports), valves, and caps. Any deviation from recommended processes can result in a failure to adequately reprocess the endoscope or endoscope accessories and lead to patient to patient transmission of pathogens risking infection. [2] Accessory equipment used to biopsy, brush, or cut tissue must be cleaned and sterilized, or, if disposable, discarded. Unfortunately, current flexible endoscopes are not designed or manufactured to withstand the heat and pressure associated with steam sterilization, the safest and most reliable method of sterilization.

Contamination of a specific type of scope, the duodenoscope, has been linked to several identified outbreaks of antibiotic-resistant infections. The duodenoscope is designed with a separate elevator channel that allows for manipulation of accessories, making it difficult to effectively clean and disinfect and therefore provides a significant challenge to making these scopes safe for patient use. Additionally, automated endoscope reprocessors (AERs) have been linked to transmission of infection as well.

This chapter provides a brief review of endoscopy-associated infection transmission and infection prevention measures to thwart them. Regardless of the practice setting, these measures must be followed to ensure the safety of patients and healthcare personnel.

Basic Principles

DEFINITION OF TERMS

Automated endoscope reprocessors (AERs) and/or *automated endoscope washer disinfectors (AEWDs)* are interchangeable terms used throughout this chapter to describe mechanical systems designed to immerse and flush the endoscope and internal channels with liquid cleaning and disinfecting/sterilizing agents; most also perform final water flush(es), alcohol rinse, and air purge.

Biofilm refers to a matrix of microorganisms and extracellular material attached to a surface that is difficult to remove.

Chemical sterilants refer to liquid chemical agents cleared by the Food and Drug Administration (FDA) for reprocessing reusable medical devices. These products are considered high-level disinfectants or sterilants depending upon exposure time, temperature, concentration, and sporicidal activity.

Cleaning refers to the physical removal of organic and inorganic material from objects and surfaces.

Duodenoscope refers toa complex endoscope instrument that has a flexible, lighted tube that is threaded through the mouth, throat, and stomach into the top of the small intestine (duodenum) used during endoscopic retrograde cholangiopancreatography (ERCP) procedure. Because they have elevator channels, they are more difficult to clean and disinfect than other types of endoscopes.

Endoscope is a broad category referring to a flexible device used to visualize the interior of a hollow organ or body space.

Endoscopic accessories refer to biopsy forceps, brushes, snares, or other devices introduced through the internal channel of the endoscope during procedures.

High-level disinfection (HLD) is the elimination of all forms of microbial life with the exception of low levels of bacterial spores.

Port refers to an opening that provides access to an internal channel of the endoscope.

Reprocessing refers to the validated cleaning and high-level disinfection or sterilization of reusable endoscopic devices by either manual or automated methods.

Sterilization is the complete elimination or destruction of all forms of microbial life.

INFECTION RISKS

The causes of endoscopy-associated infection are multifactorial. The literature contains numerous reports of outbreaks associated with defective equipment; inability to access elevator channels during cleaning and disinfection processes; inadequate cleaning and disinfection of endoscopes between patients; contaminated water rinses; contaminated automatic endoscope reprocessors; biofilm formation in endoscopes or automated reprocessors; inadequate cleaning and sterilization of endoscopic accessories; or contaminated multi-dose vials, needles, or syringes used for anesthesia. [3,4,5,6,7,8] Furthermore, there have been several reported outbreaks linked to a specific type of endoscope reprocessed with strict adherence to reprocessing procedures. [9]

Selected examples of outbreaks include:

- Hepatitis B and C associated with reuse of needles, syringes, medication vials, and fluids during the administration of anesthesia for endoscopy. [3,4,5]
- *Carbapenem-Resistant Enterobacteriaceae* (CRE) such as Klebsiella species and *Escherichia coli*. [5,8,10]
- Hepatitis C virus infections associated with inadequate endoscope reprocessing or contamination of multi-dose vials or equipment used during administration of anesthesia. [4,5,13,14,15]
- *Pseudomonas aeruginosa* and *Serratia marcescens* outbreaks associated with the inability to adequately reprocess defective bronchoscopes. [16]
- Transmission of *Mycobacterium tuberculosis* associated with inadequate manual cleaning and disinfection. [17, 18]
- *M. mesophilicum* infection associated with contaminated endoscope. [17]
- Outbreaks may not be limited to infectious events; nine episodes of anaphylaxis following cystoscopy were associated with use of orthophthalaldehyde for high-level disinfection of cystoscopes in bladder cancer patients. [20,21]

Prevention And Control Of Infections Associated With Endoscopy

Infection prevention is dependent on the education, training, and skill of the practitioner, the integrity of the device (ensuring that the equipment is free of defects), and strict adherence to reprocessing protocols. According to the Spaulding classification system, flexible endoscopes are considered semicritical devices because they come into contact with mucous membranes but do not ordinarily enter sterile tissue or the vascular system. [22] Therefore, these devices should, at a minimum, receive high-level disinfection. In response to reported problems with duodenoscopes, which are endoscopes with elevator channels, the FDA and CDC have listed scripted intervention as supplemental measures to consider for reprocessing these types of endoscopes. [9,23]

In 2011 the following societies endorsed guidelines to reprocess flexible gastrointestinal endoscopes; the Society for Healthcare Epidemiology (SHEA), American Society for Gastrointestinal Endoscopy (ASGE), American College of Gastroenterology (ACG), American Gastroenterological Association, American Society of Colon and Rectal Surgeons, Society of American Gastrointestinal Endoscopic Surgeons, Society of Gastroenterology Nurses and Associates, Association of Perioperative Registered Nurses, Accreditation Association for Ambulatory Health Care, The Joint Commission, and the Association for Professionals in Infection Control and Epidemiology, Inc. (APIC). [24]

Many of these organizations have detailed, practice-specific recommendations that have been updated following multiple reports of outbreaks. [25,26,27,28] This chapter is not intended to replace the association-specific guidelines, but to *complement* them, emphasizing those areas in which a broad range of professionals have reached consensus based on the available evidence. Everyone involved in the reprocessing of flexible gastrointestinal endoscopes should be knowledgeable of current issues in endoscopy including the most recent manufacturers' instructions, regulatory agency information and their institutional policies.

RECOMMENDATIONS FOR REPROCESSING FLEXIBLE GASTROINTESTINAL ENDOSCOPES

The reprocessing recommendations outlined in this chapter are basic steps for reprocessing endoscopes. Specific information for individual endoscopes are found in the manufacturer's instructions for use (IFU).

PRECLEANING

- Perform precleaning immediately to remove debris before bioburden can form. [27,28,30,31,32]
- Precleaning occurs in the procedure room.
- Transport endoscope to reprocessing area in closed container. [24,27,28,30]

LEAK TESTING

- Perform pressure/leak testing after each use according to manufacturer guidelines. [27,28,30,31,32]

CLEANING

Cleaning is essential before manual or automated disinfection. It is the most important step in removing the microbial burden from an endoscope.

- Disconnect and disassemble endoscope components (e.g., air/water and suction valves) as far as possible and completely immerse the endoscope and components in the detergent. [27,28,30,31]
- Meticulously clean the entire endoscope immediately after use, including valves, channels, connectors, and all detachable parts, according to the manufacturer's instructions, using a detergent compatible with the endoscope. Flush and brush all accessible channels (even if not used) to remove all organic (e.g., blood, tissue) and other residues, using appropriate adaptors.
- Repeatedly actuate the valves during cleaning to facilitate access to all surfaces. Clean the external surfaces and components of the endoscope using a soft cloth, sponge, or brushes. [3,21,22,23,24,25,26,27,28,29,30,31,32]
- Use brushes appropriate for the size of the endoscope's channel, parts, connectors, and orifices (e.g., bristles should contact all surfaces) for cleaning. Cleaning items should be disposable or thoroughly cleaned and disinfected/sterilized between uses. [27,28,30,33,36]
- Discard detergents after each use, as these products are not microbicidal and will not retard microbial growth. [27,28,29,30,32,33]

RINSE AFTER MANUAL CLEANING

- Rinse the endoscope and all removable parts with clean water
- Purge water from channels
- Dry exterior of endoscope to prevent dilution of HLD.

VISUAL INSPECTION

Visually inspect the endoscope to see that it is visibly clean before proceeding to disinfection using lighted magnification. When defective endoscopes or equipment are identified they should be removed from service immediately and repaired or replaced. Since it is impossible to visually inspect internal channels, to confirm adequacy of manual cleaning a rapid cleaning monitor can be used prior to disinfection. [30,37]

HLD

HLD is the recognized standard for flexible endoscopes. This process can be achieved either manually or with use of AER. AERs provide superior cleaning and decontamination, improved rinsing of disinfectants, and

reduced residual disinfectants in the endoscope than manual processing. Use of AERs reduces the potential for breaches from human error and non-adherence with the reprocessing guidelines. [36,59,60]

MANUAL HLD

Manual HLD should only be performed when AER are not available.

- Use a high-level disinfectant/sterilant cleared by the FDA for high-level disinfection/sterilization. [25,26,27,28,30,38,41,42,43]
- The exposure time, concentration, and temperature for disinfecting semicritical patient-care equipment varies among the FDA-cleared high-level disinfectants but must be followed at a minimum to ensure HLD/sterilization.
- The FDA label claim for high-level disinfection with more than 2% glutaraldehyde at 25°C ranges from 20 to 90 minutes depending upon the product; whereas, professional organizations support the efficacy of more than 2% glutaraldehyde for 20 minutes at 20°C for high-level disinfection after meticulous manual-cleaning. [30,37,39,40,42]
- Select a FDA cleared disinfectant/sterilant that is compatible with the endoscope. The use of any specific high-level disinfectants/sterilant on an endoscope should be avoided if the endoscope manufacturer warns against use because of functional damage (with or without cosmetic damage). [30,39,40,42]
- The selection and use of disinfectants in the healthcare field is dynamic, and products may become available that were not in existence when this guideline was written. As newer disinfectants become available, persons or committees responsible for selecting disinfectants for endoscope reprocessing should be guided by FDA clearance and product information in scientific literature. [32,39,40,44] The following link is a table of FDA-cleared liquid chemical sterilants and high level disinfectants, last updated September 2015:

  http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/ReprocessingofReusableMedicalDevices/ucm437347.htm
- Completely immerse the endoscope and endoscope components in the high-level disinfectant/sterilant and ensure all channels are perfused. Non-immersible gastrointestinal endoscopes are no longer acceptable. [27,28,30,32]
- Ensure that disinfectant/sterilant is completely removed from endoscope by rinsing with large amounts of water after processing is complete. Follow manufacturer's guidelines for disinfectant/sterilant removal.

HLD WITH AER

- If an AER is used, ensure that the endoscope and endoscope components can be effectively reprocessed in the AER (e.g., the elevator wire channel of duodenoscopes may not be effectively disinfected by AERs, and this step must be performed manually). Users should obtain and review model-specific reprocessing protocols from both the endoscope and AER manufacturers and check for compatibility. [27,28,30,34]
- If an AER is used, place the endoscope and endoscope components in the reprocessor and attach all channel connectors according to the AER and endoscope manufacturers' instructions to ensure exposure of all internal surfaces with the high-level disinfectant/chemical sterilant. [27,28,30,34]
- If an AER cycle is interrupted, high-level disinfection or sterilization cannot be assured and therefore the entire cycle must be repeated. [24,28]
- Because design flaws have compromised the effectiveness of AERs, the infection prevention staff should routinely review FDA advisories, manufacturer alerts, and the scientific literature for reports of AER deficiencies that may lead to infection. [24]
- The following link provides information on the FDA's Evaluation Automated Endoscope Reprocessors (AERs):

  http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/ReprocessingofReusableMedicalDevices/ucm483896.htm

RINSE AFTER HLD

- After high-level disinfection, thoroughly rinse all surfaces and removable parts, and flush all channels of the endoscope and its removable parts. Rinsing prevents exposure to chemical residue.

- Discard the rinse water after each use/cycle.

DRYING

- The final drying steps greatly reduce the possibility of recontamination of the endoscope by waterborne microorganisms. [24,25,26,27,28,32,45]
- Flush the channels with 70%–90% ethyl or isopropyl alcohol.
- Dry using medical grade air.
- Remove all adaptors.
- Dry exterior of endoscope with a soft, clean, lint-free towel.

STORAGE

- When storing the endoscope, hang it in a vertical position to facilitate drying (with caps, valves and other detachable components removed as per manufacturer instructions). [24,26,28,32,45]
- Endoscopes should be stored in a manner that will protect the endoscope from contamination. Current evidence on maximum storage time to ensure devices are safe for patient use is inconsistent therefore this remains an unresolved issue.
- Store the caps and other equipment linked to the scope together after HLD to ease in look back investigations when the HLD cannot be assured.

Both conventional and drying storage cabinets are available. Drying cabinets provide a controlled environment to help ensure that the endoscope channels remain dry. [24,25,30,35,45]

ENHANCED REPROCESSING FOR DUODENOSCOPES

In August of 2014 the FDA released a safety alert to address supplemental measures to enhance duodenoscope reprocessing. [46] The FDA recommends that combined with strict adherence to the duodenoscope manufacturer's reprocessing instructions, the following supplemental measures should be considered:

- Microbiological Culturing
- Ethylene Oxide Sterilization
- Use of a Liquid Chemical Sterilant Processing System
- Repeat High-Level Disinfection.

The following link takes you to this alert where each of these is described in more detail:

http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm454766.htm

ADDITIONAL PRECAUTIONS DURING BRONCHOSCOPY

There are guidelines specific to bronchoscopy to prevent transmission of organisms that potentially transmit via airborne droplet nuclei such as *M. tuberculosis*: [53,54]

- All bronchoscopy personnel should undergo routine influenza and hepatitis B immunization and tuberculin screening, evaluation, and follow-up as indicated.
- All bronchoscopes should be fully immersible and have disposable biopsy caps or valves. Disposable biopsy caps or valves should be discarded after every procedure and not reused.
- Patients undergoing aerosol-generating procedures, including bronchoscopy, should be screened for symptoms suggestive of tuberculosis or other infections capable of being transmitted via airborne droplet nuclei. If patients are suspected of having these conditions, the following measures should be implemented:
  - Bronchoscopy should not be performed unless absolutely necessary.
  - If medically necessary, bronchoscopy should only be performed in a room that meets the ventilation requirements for an airborne infection isolation room (negative directional air flow, a minimum of 12 air exchanges per hour and direct exhaust to the outside more than 25 feet from an air intake or discharged through a high efficiency particulate air filtration system).

- HCP should wear appropriate personal protective equipment including a fit-tested respirator or power air-purifying respirator (PAPR).
- After the procedure patients may continue to cough and pose additional risk; therefore, airborne precautions should be maintained.
- The room should not be used for another patient until adequate time has elapsed for potential airborne contaminants to be removed.
- The room and potentially contaminated surfaces should be thoroughly cleaned before use for another patient.
- Some states, such as California, have additional regulations around the performance of bronchoscopy.

DISPOSABLE OR REUSABLE ENDOSCOPIC ACCESSORIES

Reusable endoscopic accessories (e.g., biopsy forceps or other cutting instruments) that break the mucosal barrier should be mechanically cleaned as described earlier and then sterilized between each patient use (high-level disinfection is not appropriate). [3,11,27,28,30,32,34,35]

Disposable endoscopic accessories should be discarded immediately after use. Facilities considering reuse and reprocessing of single use devices must comply with FDA requirements (see also **Chapter 32, Reprocessing Single-Use Devices**).

- High-level disinfect or sterilize the water bottle (used for cleaning the lens and irrigation during the procedure), and its connecting tube at least daily. Sterile water should be used to fill the water bottle.

ENVIRONMENTAL SAFETY

- Reprocessing of contaminated equipment should be performed in a separate area or room, not in the endoscopy procedure room.
- The area must have adequate space for reprocessing, appropriate airflow and ventilation for the selection and method of disinfection/sterilization, appropriate work flow pattern (movement from dirty to clean minimizing the opportunity for cross-contamination), and appropriate storage facilities. The area should be restricted to authorized personnel. [24,28,30,52,55,56]
- Air-exchange equipment (ventilation system, exhaust hoods, etc.) should be used to minimize the exposure of all persons to potentially toxic vapors (e.g., glutaraldehyde). The vapor concentration of the chemical sterilant used should not exceed allowable limits (e.g., those of the American Conference of Governmental Industrial Hygienists, Occupational Safety and Health Administration [OSHA]). Although organic vapor respirators appropriate for chemical exposures can provide respiratory protection (e.g., in the event of spills), they are not intended for routine use and are not a substitute for adequate ventilation, vapor recovery systems, and work practice controls. [25,28,30,47]
- Personal protective equipment (gloves, gowns, eyewear, respiratory protection devices, etc.) should be readily available and should be used, as appropriate, to protect workers from exposure to chemicals, blood, or other potentially infectious material (OPIM). [30,39,49]

QUALITY ASSURANCE

Many factors affect the safe use of endoscopes. These include; the inherent complexity of the instruments, failure to strictly adhere to the manufacturer's instructions for use, equipment malfunction, and the lack of standard processes. Quality assurance programs must include routine supervision, training, and competency review of all endoscopy staff. Infection prevention policies and protocols need to be accessible to staff at all times. This includes the current manufacturer instructions for use, for the equipment being disinfected/sterilized, the equipment used for disinfectant/sterilants, and the disinfectant/sterilant being used. Tracer tools may be utilized to evaluate endoscopy practices in order to capture practice deficiencies. One example of a tracer tool was published by The Joint Commission, 2016. [61]

MONITORING

- Maintain a log indicating for each procedure the patient's name and medical record number (if available), the procedure, the endoscopist, and the serial number or other identifier of the endoscope (and AEWD, if used) to assist in an outbreak investigation. Endoscopes and accessories should be traced from patient use

through the entire reprocessing process with each phase documented. Documentation should include the staff involved at each stage.

- Healthcare facilities should develop protocols to ensure that users can readily identify whether an endoscope is contaminated or is ready for patient use.
- Any doubts that an endoscope has been properly disinfected the endoscope should be removed from service and reprocessed.
- Perform routine testing of the liquid sterilant/high-level disinfectant to ensure minimal effective concentration (MEC) of the active ingredient per the manufacturer guidelines and document the results. If the chemical indicator shows that the concentration is less than the MEC, the solution should be discarded. [24,25,30,32,35,39]
- Records of this testing should be maintained per regulatory bodies (refer to guidelines for individual states).
- Discard the liquid sterilant/high-level disinfectant at the end of its reuse life (which may be single use) regardless of the MEC. If additional liquid sterilant/high-level disinfectant is added to an AEWD (or basin, if manually disinfected), the reuse life should be determined by the first use/activation of the original solution (i.e., the practice of “topping off” of a liquid sterilant/high-level disinfectant pool does not extend the reuse life of the liquid sterilant/high-level disinfectant). [28,32]
- The utility of routine environmental microbiological testing of endoscopes for quality assurance has not been established. Interim guidelines from the CDC address culturing of duodenoscopes specifically, due CRE outbreaks associated with ECRPs are located at the following link retrieved on October 4, 2016. Because these are interim guidelines, they may be updated at any point. They may be used based on facility decision for other type of scopes.

  http://www.cdc.gov/hai/organisms/cre/cre-duodenoscope-surveillance-protocol.html

COMPETENCY

- Personnel assigned to reprocess endoscopes should receive education on infection prevention.
- Personnel assigned to reprocess endoscopes should receive device-specific reprocessing instructions (i.e., endoscope and/or AEWD manufacturer, as needed) to ensure proper cleaning and high-level disinfection or sterilization.
- Competency testing of personnel reprocessing endoscopes should be done on a regular basis (e.g., commencement of employment, annually). Competency testing should also be performed for new models of endoscopes, accessories, and automatic reprocessors when they are introduced to the unit.
- Temporary personnel should not be allowed to reprocess endoscopes until competency has been established. [25,28,30]
- All personnel using chemicals should be educated about the biological and chemical hazards present while performing procedures that use disinfectants. [30,39,48] Records of employee competencies should be maintained for personnel and compliance records.

RESPONSE TO OUTBREAKS

Infection preventionists play a critical role in surveillance and control of device-associated outbreaks. Surveillance must include all sites where these procedures are being performed, whether in the inpatient or outpatient setting. Early identification and prompt reporting of a problem can help determine the cause and extent of the problem as well as limit further transmission. Therefore, these events should be reported promptly to appropriate public health authorities and the manufacturers of the devices, as well as internally per facility policy. [25,28,30,51,57]

- Endoscopy-associated infections should be reported to:
  - Persons responsible for infection prevention at the facility.
  - Physician(s) responsible for the care of the patient(s).
  - The appropriate public health agency (state or local health department as required by state law or regulation).
  - FDA
  - CDC
  - The manufacturer(s) of the endoscope, disinfectant/sterilant, and AEWD (if used).

- Once a possible failure has occurred, the medical items improperly disinfected/sterilized should be impounded, labeled, and stored in an area where they can't be inadvertently used. [57]
- Questionable disinfection/sterilization units should be removed from service until proper functioning has been verified. [57]
- Isolates should be obtained to identify the source or reservoir of infection, mechanism of transmission and effectiveness of control measures or to evaluate potential cross-contamination while obtaining, transporting, or handling specimens in the laboratory.
- In the setting of an outbreak caused by a suspected infectious or chemical etiology, the environmental sampling should be performed according to standard outbreak investigation. [25,30,50,51]
- Evaluate the endoscopic practices and procedures, including the devices used, the technique of the practitioner, and handling of equipment.

Adverse Event Reporting

Serious adverse events (including breaches on patient safety and infection prevention) associated with an endoscope, endoscope accessory, AER, or disinfectant/sterilant should be promptly reported to facility leadership, infection prevention, appropriate healthcare agencies, the manufacturer of the device(s), and the FDA, regardless of whether or not all the details are available or causality has been determined. According to the FDA, an adverse event is considered serious when the patient requires intervention to prevent permanent impairment or damage; when the patient requires hospitalization or prolonged hospitalization; when the event is life-threatening; when the event leads to significant, persistent, or permanent disability; or when the patient outcome is death.

Reports can be submitted to the FDA by phone, fax, or Internet. Currently, the FDA post market surveillance system relies on device manufacturers to self-monitor and self-report design modifications, testing in real world settings, and the occurrence of adverse events. The United States Senate HEALTH, EDUCATION, LABOR, AND PENSIONS COMMITTEE made recommendations that include updating FDA guidance , National Medical Device Evaluation System (NMDES), and enforcement of compliance with medical device reporting. [57]

Equipment Selection

Potential infection risks associated with non-disposable endoscopic equipment should be a major criterion in the selection process. Facilities should purchase endoscopes that are fully immersible and with internal suction and operating channels that can be manually brushed through their entire length. Individuals responsible for infection prevention and reprocessing at the healthcare facility should be consulted when new devices are introduced to ensure that infection control considerations are included in the reprocessing policies. Healthcare personnel should be able to readily identify devices that are reprocessed and ready for patient use. The following additional questions should be considered:

- Can the instrument undergo steam sterilization? If yes, this is the reprocessing method of choice.
- If the instrument cannot undergo steam sterilization, what methods can be used to ensure that all components, internal channels, and external surfaces are adequately cleaned and that there is sufficient contact with the high-level disinfectant or sterilant?
- Is an AEWD that claims manual cleaning prior to reprocessing acceptable to use? Some AEWD have received FDA approval to claim that manual cleaning is not necessary prior to reprocessing in the automated system; the ASGE does not recommend eliminating manual cleaning until more experience in practice settings has documented the safety of eliminating this critical step. [28,56]
- Should reusable or disposable endoscope accessories be used? If a facility elects to use reusable biopsy forceps, snares, brushes, or other spring-loaded devices, strict adherence to manufacturer reprocessing recommendations must be followed. As with any piece of equipment, a visual inspection before, during, and after use is recommended.

Unresolved Issues

Although beyond the scope of this chapter, the following are selected unresolved issues with regard to reprocessing flexible endoscopic equipment using liquid chemical sterilants and high-level disinfectants:

- Can manual cleaning steps be eliminated in AEWDs that have received FDA approval for an automated cleaning process?
- Should routine bacteriologic sampling of rinse water be performed when reprocessing flexible endoscopes in AERs?
- Should standardized surveillance procedures be required?
- Should there be a mandatory training program or certification for persons responsible for reprocessing endoscopic equipment? If so, what criteria should be used?
- Are current recommendations sufficient to prevent transmission of variant CJD or other prion infections?

Conclusions

Flexible endoscopy has become an invaluable diagnostic and therapeutic tool. As with all diagnostic and therapeutic procedures, there are intrinsic and extrinsic risks of complications. To minimize the risk of infection, healthcare providers must ensure that their equipment is designed and maintained properly and that guidelines for reprocessing are strictly followed.

Several factors impact the effectiveness of reprocessing, including complex design features, lack of knowledge or unfamiliarity with endoscope channels, accessories, and specific steps, inadequate training, and lack of quality control measures. Drug-resistant infection outbreaks have occurred despite adherence to reprocessing guidelines in a specific type of endoscope. [2,57,58,59,60] Transmission of infections linked to endoscopy may be unrecognized because of a lack of adequate surveillance and reporting. Infection preventionists play a critical role in surveillance and control of device-associated outbreaks.

Future Trends

The practice of endoscopy and performance of minimally invasive procedures will inevitably continue to grow and expand in virtually every area of surgical practice. Reducing the risk of infections must be a fundamental priority for device manufacturers, the regulatory bodies, professional organizations and the clinicians who use the devices. As with previous generations, the clinical, scientific, and engineering communities must continue to work together to address critical infection prevention and patient safety issues associated with the instruments and practice of endoscopy. A reasonable goal is to design, manufacture, and use endoscopes and accessories that are either disposable or able to undergo steam sterilization. Additionally the development of methods that can eliminate biofilm, standardizing surveillance, and improving reporting of transmission of infection from contaminated endoscopes and device failures. This would enhance the ease and feasibility of ensuring adequately reprocessed devices and safer procedures critical to patient and HCP safety.

International Perspective

Endoscopic procedures are performed throughout the world. Patient safety and infection prevention are of primary concern in addition to protecting HCP. Many countries have already adopted guidelines for process validation and routine surveillance for endoscope. Endoscopy practices in countries lacking specific standards, recommendations, or guidelines may adapt those from professional organizations with consideration of scientific-based evidence and feasibility in applying the resources available.

Supplemental Resources

American College of Chest Physicians: Available at: **http://www.chestnet.org**

American Gastroenterological Association: Available at: **http://www.gastro.org/wmspage.cfm?parm152**

American Society of Colon and Rectal Surgeons: Available at: **http://www.fascrs.org**

American Society for Gastrointestinal Endoscopy: Available at: **http://www.asge.org**

Association of periOperative Registered Nurses: Available at: **http://www.aorn.org**

Centers for Disease Control and Prevention: Available at: **http://www.cdc.gov**

FDA: Available at: **http://www.fda.gov**

Society of American Gastrointestinal Endoscopic Surgeons: Available at: **http://www.sages.org**

Society of Gastroenterology Nurses and Associates: Available at: **http://www.sgna.org**

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Home Care

Author(s): Carole Yeung, RN, CIC
Clinical Practice Specialist, Infection Control

Baptist Home Health Network
Little Rock, AR

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Abstract

Acute care facilities in the United States and Canada have been under pressure for the past two decades to reduce lengths of stay and more recently to reduce healthcare costs and improve the quality of care. Extended length of stay also increases the risk of healthcare-associated infections and other medical errors. The percentage of the U.S. population over the age of 65 is increasing every year. As a result, the number of people receiving healthcare at home has increased and the care provided has become increasingly complex, with many of these people having chronic conditions. Although the principles of infection prevention apply in all healthcare settings, there are differences in the practical application of the principles when healthcare is delivered in the home. This chapter addresses the challenges involved in developing or improving a home care infection prevention and control program and the resources available to assist in meeting some of these challenges.

Key Concepts

- Home care organizations provide a wide range of healthcare services and serve patients who have a wide variety of healthcare needs.
- Each home care agency is different in regard to the services provided, patients served, and resources (including human) available.
- The complexity of the patients may be very high, as the incidence of chronic diseases is increasing and the care needed may include advances in technology.
- The incidence of multidrug-resistant organisms in the community and in hospital-discharged patients is increasing.
- There is increasing use of technology in the home, with a potential for contamination with microorganisms.

- Although there is certainly some risk of healthcare-associated infections when healthcare is delivered in the home, the scope of this risk is poorly understood and more research is needed.
- The goal of the home care agency is to provide healthcare in a manner that benefits the patient and achieves the desired health outcomes while protecting the health and safety of the patient, healthcare personnel, and community.

Background

Home healthcare (HHC) collectively refers to many types of services, including nursing, rehabilitation, hospice, home infusion, telemedicine, and other aspects of care. Professional services are provided by nurses, social workers, physical therapists, occupational therapists, speech therapists, and dieticians, whereas caregivers include home care aides, respite workers, and therapy aides. HHC agencies may also use volunteers in a variety of ways in the patient's home. Home settings vary and may be situated in a single-family dwelling, apartment, assisted-living facility, personal care home, or other location.[1,2,3,4,5,6] Some HHC agencies are providing hospital care that provides safe, high-quality care to older adults in the comfort of their homes.[7]

The recipients of HHC often have unique needs related to their circumstances, which may include acute illness, injury, recovery from surgery, cancer treatment, chronic disease, temporary or permanent disability, or end-of-life care.[1,2,4,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22] Today, 133 million people—almost half of all Americans—live with a chronic condition. As the population ages, the number will increase to 157 million by 2020. Thirty-seven percent more Americans are projected to have a chronic condition by 2030, an increase of 46 million people. By 2030, 20 percent of the population will be people age 65 or older with a chronic condition.[23] Women are more likely to have a chronic condition, with hypertension being the most common.[24] According to the Clarity Report, seniors fear the loss of independence and/or moving into a nursing home more than death. Also, in the same report, aging in place (i.e., the ability to live in one's own home—wherever that might be—for as long as confidently and comfortably possible) is very important to the vast majority of seniors (89 percent), and more than half (53 percent) were concerned about their ability to do so.[25] Services are provided to persons of all ages. In the future, services may need to be expanded in the home environment to meet the desired need of those who are aging in place, including the use of technology to ensure safety in the home.

In the United States, the Centers for Medicare & Medicaid Services (CMS) is the largest single payer for home care services, primarily through the Medicare program for homebound Medicare beneficiaries.[1,5] Medicaid payment for home care is available to those who do not qualify for Medicare coverage (provided they meet the criteria and application procedures); however, Medicaid coverage varies by state.[1,5] Chronic disease management approaches are applicable to those with human immunodeficiency virus/acquired immunodeficiecny syndrome and other infectious diseases (e.g., manage infusions and vascular access), cardiology (e.g., heart failure, patients waiting for cardiac transplants, extended-care pathways, infusion, electrocardiograms), cancer (e.g., chemotherapy, radiation, palliation, hospice), dialysis/end-stage renal disease, diabetes, and chronic lung disease.[1] Home care clients include the following special populations: pediatric, psychiatric, obstetrical and gynecological, surgical and orthopedic, ventilator-dependent (e.g., amyotrophic lateral sclerosis), patients with multiple sclerosis or cerebral palsy, and persons with disabilities.

According to the U.S. Department of Health and Human Services (HHS), in 2007 there were 14,000 home health and hospice care agencies. Of these, 74.8 percent provided home health services only, 15.3 percent hospice care services only, and 9.9 percent were mixed.[5] The number of patients seeking HHC, acuity level of the patients, and ability to use more invasive devices and technology in the home setting continues to grow.[1,2,5]

Although it is clear that there is a risk for infection in patients receiving HHC, the epidemiology is not well defined. The presence of an indwelling medical device (e.g., vascular access) poses an increased risk of healthcare-associated infection (HAI). Patients receiving home care frequently have underlying chronic medical conditions that make them more vulnerable to infection. Home care organizations frequently provide care to patients with suppressed or deficient immune systems.[1,15,18] Studies conducted by the Centers for Disease Control and Prevention (CDC) in collaboration with the Missouri Alliance for Home Care (MAHC) and the Missouri Department of Health suggest that an estimated 1.2 million patients receiving home care acquire infections each year.[4]

In the past, HHC agencies have primarily relied on infection prevention guidelines and recommendations developed for hospitals as the basis for developing HHC infection prevention and control programs. As healthcare shifts away from acute care hospitals toward other healthcare settings, the healthcare community has recognized the need to provide guidance for improving patient outcomes in outpatient and community settings. In recent years, infection prevention resources available to HHC agencies have increased. The CDC, a renowned source for relevant infection prevention guidelines for acute care hospitals, has recognized that infection prevention methods are applicable across the healthcare continuum. Also the Healthcare Infection Control Practices Advisory Committee (HICPAC), a federal advisory committee made up of 14 infection prevention experts providing guidance to the CDC, has aligned its responsibilities with the evolving delivery of healthcare.[14,26,27,28,29,30,31]

The focus of the HHC agency is to provide not just patient care but also preventative care (e.g., promoting vaccine-preventable diseases such as influenza) and to prevent complications of chronic disease. The infection prevention and control program should be structured around the particular characteristics of the patient population and the HHC agency in order to most effectively use the resources available.[2,14,32] The HHC agency must comply with federal, state, provincial, and local regulatory requirements as applicable (see also **4. Accrediting and Regulatory Agencies**).

Basic Principles

The Environment of Care

One of the major differences between healthcare delivered in an inpatient facility and HHC delivered in the home care setting is that the HHC personnel have much less control over the physical environment. The home environment must be assessed to determine whether the HHC agency can safely provide the services needed. The setting should be assessed for cleanliness, temperature control, running water, toilet facilities, and infestation with insects or rodents. Although there are few studies linking infections to home hygiene, there are opportunities to improve the HHC environment (e.g., through education, supplies, procedures, support).[1,2,33]

Providers of Care

In HHC, the majority of the patient's care is provided by someone other than an HHC professional. The healthcare professional may be in the home for only a few hours per week. To reduce the risk of infection, patient and family education should include information about hand hygiene and infection prevention practices specific to the patient's care (wound care, indwelling urinary catheters, intravenous lines, etc).[34,35] Many multidrug-resistant organisms (MDROs) can survive in the environment for days to months; however, most studies have been conducted in acute or long-term care (LTC) facilities.[36] It has been documented that the influenza virus and methicillin-resistant *Staphylococcus aureus* bacteria can survive on commonly touched household surfaces.[37,38] Patients who are colonized and/or infected with MDROs are frequently admitted to HHC, and the importance of maintaining a clean environment—especially high-touch areas—should be addressed. In addition, education should be provided about the signs and symptoms of infection and what to do if infection or other poor outcome is suspected.[34] Information for specific infections and microorganisms is available at the CDC website.[39]

Recognition of the influence of societal and cultural beliefs of HHC patients and their families must be considered when providing care and education. This is especially important for long-term conditions and hospice care.[10,20,22,40,41] (see also **57. Hospice and Palliative Care**).

Hand Hygiene

Hand hygiene is the single most important element in infection prevention in all healthcare settings. The availability of potable water, liquid hand soap, and paper towels may not be guaranteed unless they are brought into the home by healthcare personnel (HCP). For that reason, alcohol-based hand rubs for hand hygiene have been used in home care for many years. The use of these products for hand hygiene is acceptable provided hands are not visibly soiled or contaminated with proteinaceous material such as blood or feces. In these situations, hands should be washed with soap and water. All products for hand hygiene should be approved (with employee input) and provided by the HHC agency.[28,33] (See also **27. Hand Hygiene**, and **30 Aseptic Technique**).

Precautions for Preventing the Transmission of Infectious Agents in the Home

Standard Precautions are essential to preventing the transmission of infectious agents. In addition to hand hygiene, respiratory hygiene/cough etiquette is essential to contain respiratory secretions to prevent droplet and fomite transmission of respiratory pathogens, especially during seasonal outbreaks of viral respiratory tract infections. Personal protective equipment (e.g., gloves, gowns, face mask, eye protection) should always be used if there is a potential for exposure to blood and/or body substances of any patient. The use of Standard Precautions (using gowns and gloves with uncontrolled secretions, pressure ulcers, draining wounds, stool incontinence, and ostomy tubes and bags) will also prevent the transmission of MDROs.[31,32,42] The routine use of gloves and gowns to prevent MDRO transmission is an unresolved issue. The need for Contact Precautions depends on several variables, including if the patient has uncontrolled secretions or drainage or evidence of MDRO transmission from one patient to another in the HHC agency, as well as whether the HCC agency has evidence that there is poor compliance with Standard Precautions.HHC referral information, not only from healthcare facilities but also physician offices, should include the patient's MDRO status.[43] HHC agencies should also notify receiving healthcare facilities and personnel prior to transfer of patients with MDROs to that facility.[31,32,33] Hospital patients are at increased risk for transmission because of their underlying illness, increased

contact with HCP and other patients, and interventions that breach the first line of defenses.[32](See also Chapter 29 Isolation Precautions.)

Supply and Equipment Management

Clean and sterile supplies must be transported to and stored in the home in a manner that will keep them dry and protected from contamination. In a heavily soiled environment, plastic storage containers may be used. When a product has been stored in the home, the integrity of the item should be assessed before each use. If an item, purchased as clean or sterile, is discovered to have a wrapper that is no longer intact or has apparent water stains, the item should be discarded.[2,14]

Supplies kept in the provider's home care bag or vehicle must be stored and handled without compromising the integrity of the supplies. The home care bag itself is a noncritical item and does not come into contact with the patient, though it may contain some critical or semicritical items. There is no evidence that placing a barrier under the bag in the patient's home prevents the transmission of infection. Hand hygiene should be performed before reaching into the bag. Expiration dates on supplies, if applicable, should be checked on a regular basis to prevent the use of outdated supplies.[2]

Equipment in HHC is becoming more technologically advanced with the use of cameras, two-way videos, etc.[44]All nondisposable patient care equipment should be cleaned the same, per manufacturer guidelines, regardless of the patient's infectious status.[33]Disinfectants used should be approved by the HHC agency. The HHC provider should limit the amount of nondisposable patient care equipment brought into the home if the patient is known to be infected or colonized with MDROs. Whenever possible, leave this equipment in the home until the patient discharges from home care services. If noncritical patient care equipment (e.g., stethoscope) cannot remain in the home, clean and disinfect items before taking them from the home using a low- to intermediate-level disinfectant. Alternatively, place contaminated reusable items in a plastic bag for transport and subsequent cleaning and disinfection.[31,34]

Waste Management

Waste generated in the home setting should be handled as if it could transmit infectious agents.[45,46] (See also **21. Risk Factors Facilitating Transmission of Infectious Agents** **29. Isolation Precautions (Transmission-based Precautions)**; and **105. Minimizing Exposure to Blood and Body Fluids**.) Nonsharp waste should be placed into designated containers (e.g., plastic bag) and followed by hand hygiene procedures. Surfaces that may become contaminated should be cleaned and disinfected with an HHC agency-approved disinfectant. The U.S. Occupational Safety and Health Administration (OSHA), in its enforcement procedures for bloodborne pathogens, has stated that HHC agencies will not be held responsible for the disposal of regulated waste in the home.[46]Household trash is regulated at the state and local government level. In certain circumstances, additional guidance for waste handling and disposal may be provided based upon emerging pathogens (see also **96. Viral Hemorrhagic Fevers**, and **73. Creutzfeldt-Jakob Disease and Other Prion Diseases**).

Safe practices are required when handling sharps (e.g., needles, lancets), which must be disposed of appropriately to prevent injuries. There are no federal regulations governing the safe disposal of needles and syringes in the home, and unfortunately many may end up in the household trash.[47]The infection preventionist (IP) or other HHC provider should ensure that home care clients are instructed in the proper disposal of sharps according to applicable laws and regulations. One suggestion that is

common and improves safety of sharp disposal in the home is the use of a hard plastic container such as a bleach container for disposal of sharps. The lid may be taped in place prior to trash disposal. The container is NOT marked as biohazardous waste. In addition, the Coalition for Safe Community Disposal promotes public awareness and solutions for safe disposal of needles, syringes, and other sharps in the community. These recommendations no longer suggest that residents throw their used needles in the garbage, but encourage disposal of their used needles through other means such as community drop-off programs, household hazardous waste facilities, sharps mail-back programs, or at-home needle destruction devices.[45,48,49]

Home Care Infection Prevention Program

INFECTION SURVEILLANCE IN HOME CARE

The purpose of surveillance in home health and hospice care is to assess the safety and quality of patient care by establishing a baseline at each agency, monitor trends within an agency, use findings to improve care, and prevent HAI and other complications. Primary outcome objectives include reductions in morbidity, emergent care, acute care hospitalizations, and cost.[48]Infection surveillance is the cornerstone of the infection prevention and control program (see also **11. Surveillance**).

There are many challenges for an infection surveillance program in home care, including the loss of patients to follow-up, lack of laboratory data and radiological imaging, and difficulty in obtaining numerator and denominator data.[2,48]In addition, the person assigned responsibility for infection prevention may have many other responsibilities and may not have adequate training in infection surveillance, prevention, and control.[2]In spite of these obstacles, infection surveillance provides an important means of measuring healthcare outcomes in the HHC setting. Infection surveillance also provides a mechanism for identifying conditions that must be reported to the public health department in accordance with state regulations (see also **4. Accrediting and Regulatory Agencies**, and **117. Public Health**).

Assessment of Populations Served and Services Provided

The populations served and services provided are primary considerations in planning an HHC infection surveillance program. For example, the surveillance priorities may be different for an agency providing care for a large number of oncology patients than for an agency that rarely provides care for an oncology patient. When a home care agency provides care for clients with venous access devices for infusion therapy, surveillance for catheter-associated bloodstream infections will likely be a high priority (see also **18. Patient Safety**; **22. Microbial Pathogenicity and Host Response**; **23. The Immunocompromised Host**, and other chapters addressing specific patient populations).

Review of Existing Infection Data

Review of any available infection data will be helpful in establishing surveillance priorities. Although surveillance for catheter-associated urinary tract infections may not be a priority in an agency that does not care for indwelling urinary catheters, the priorities may be different for a home care agency with data indicating both that such infections are frequently identified in the agency's patient population and that these infections are associated with increased morbidity and costs. If previously obtained infection surveillance data indicate that MDROs are occurring in the agency's patient population, this data could

provide direction for the surveillance plan (see also **26. Antimicrobials and Resistance**, and **10. General Principles of Epidemiology**).

The Surveillance Plan

The surveillance plan should define the scope of data gathering. Although it is unlikely to be feasible or desirable to include surveillance for all infections in the long-range surveillance plan, comprehensive data collection for all infections for a defined period of time may be valuable. The resulting data could provide baseline information necessary for the development of a long-range surveillance plan and for future recognition of epidemics and outbreaks (see also **117. Public Health**, and **120. Infectious Disease Disasters: Bioterrorism, Emerging Infections, and Pandemics**). The long-range plan should focus on frequently occurring infections, high-risk infections, and/or infections for which interventions are very likely to result in prevention. The outcomes selected and the method (prospective or retrospective) must be feasible given available resources.

In addition to infections, the surveillance plan may include other infection prevention measures. For example, it may include calculating rates of participation in the agency's immunization program for HCP (e.g., Hepatitis B, influenza, pneumonia, measles/mumps/rubella, varicella vaccines), rates of work-related exposure to communicable disease, occupational illness, and work-related injuries (e.g., sharps injury). The plan may also include process surveillance for rates of compliance with infection prevention policies, such as management of intravenous access devices and sites, wound care, supply and equipment management, hand hygiene, and the timely provision of appropriate vaccines for clients. The HHC agency's tuberculosis (TB) prevention and control program may also be included in the surveillance program (e.g., screening of clients and staff, and compliance with TB skin testing program). Attendance at the infection prevention education program may be considered a surveillance measurement.[2,3,33]

Home Care Infection Surveillance Definitions

Infection definition for the purpose of surveillance definitions must be selected before initiating a surveillance program. In February 2008, APIC-HICPAC published surveillance definitions for HHC and hospice.[48] Definitions should be consistently used in the collection, analysis, and reporting of surveillance data.

Collecting the Data

The surveillance plan must specify at a minimum data to be collected, the data collectors, and the methodology. Both numerator (infections) and denominator (number of persons at risk or number of days of risk or device days) data are needed to calculate infection rates. Unlike acute care hospitals and long-term care facilities, it may not be feasible for the IP in HHC to directly collect surveillance data. Instead, clinical staff may be the primary data collectors in an HHC agency.[2] Thorough training in surveillance for all data collectors is essential to reduce problems with inter-rater reliability (the degree of consistency between two raters). The IP may be instrumental in training data collectors to minimize these problems.

Rhinehart and McGoldrick suggest a two-phase process for infection surveillance in which clinical staff report suspected infections based on explicit criteria and the IP investigates all suspected infections to identify home care-associated infections.[2] Although collaboration in establishing the surveillance plan has value in all healthcare settings, collaboration is essential when the clinical staff function as data

collectors. In addition, the forms used for data collection must be carefully designed to facilitate consistency in the data collection process. Education about the data collection process must be provided for the clinical staff to reduce problems with the reliability of the data. Written guidelines for data collection should also be available as a ready reference in the data collection and recording process. In addition, it is essential that periodic assessment of the data collection process be conducted to ensure consistency in the process over time. When there is turnover of personnel, new clinical personnel whose role includes data collection must receive a thorough orientation to their infection surveillance responsibilities.

Another method to identify potential infections is to use the CMS Outcome and Assessment Information Set (OASIS) data. OASIS is a broad group of data elements that are collected to measure patient outcomes for purposes of outcome-based quality improvement. This data is collected at start of care, recertification at 60 days, transfer, and discharge. The OASIS data identifies 20 reasons the patient was transferred to a hospital or received emergency care at any time during their care. Four of these reasons are related to infection: (1) respiratory infection (pneumonia, bronchitis), (2) urinary tract infection (UTI), (3) intravenous (IV) catheter-related infection or complication, and (4) wound infection, deteriorating wound status, new lesion/ulcer. This does not mean that the patient meets the surveillance definition for a HAI but the patient nevertheless warrants additional follow-up. OASIS also collects data regarding if the patient has been treated for a UTI 14 days prior to discharge. If the patient has been treated for a UTI, again it does not mean the patient meets the surveillance definition for a UTI, but the patient nevertheless warrants additional follow-up.[6]

Pilot Project

When initiating a new surveillance plan, conducting a pilot of the data collection process with a small number of clinical staff may be useful for identification of opportunities to improve the system. The goal of a pilot is to improve the quality of the collected data and reduce frustration on the part of the clinical staff when the plan is fully implemented. Data collected during the pilot project should not be considered baseline data and should not be used to develop reports for dissemination within the organization.

Aggregation and Analysis of Surveillance Data

At the end of the collection period when the numerator and denominator data have been collected, the data must be aggregated and reports prepared. The time period for collecting data may not be the same for each clinical outcome to be studied. Although the time period used in acute care hospitals is usually monthly, there is no set time period established as ideal for data collection in nonhospital infection surveillance. For frequently occurring infections, a monthly time period for data collection may be preferable. However, it may be determined that quarterly reporting is more practical. For infections or events that occur infrequently, annual reporting may be acceptable. In the interim, the IP should ideally review collected data on a regular basis. It is important to recognize that patterns and trends may not be apparent while the data are in the raw form. The IP should summarize the data into a report that is easy for the intended audience to understand. Simple tables, charts, and graphs are usually more effective in communicating the results of surveillance.

Internal and External Reporting of Healthcare-associated Infections

After the surveillance plan has been implemented and the data collected, collated, analyzed, and summarized into reports, the findings must be reported. The HAI data should be reported to leaders in the agency's outcome improvement efforts and all the clinical staff. The clinical staff involved in data

collection should have the opportunity to see the results of the collection efforts and should be involved in the planning of interventions.

HHC surveillance may reveal infections associated with care received in an inpatient or outpatient facility. For example, a surgical site infection that becomes apparent after the patient has been discharged from a hospital and admitted to the home care agency may be reported to the infection prevention department or IP in the facility where the surgery was performed. On the other hand, when a home care patient is admitted to the hospital and discovered to have an infection that apparently developed while the patient was receiving home care, this information may be reported to the home care agency. The information will allow the HHC agency to investigate the infection and, if appropriate, include it in the agency's surveillance data.[33]

Public Health and Required Reporting

Every state and province has a list of diseases that must be reported to the public health department and the time frames for reporting. HHC agencies have an important role in the prevention and control of communicable disease. Surveillance plans should include strategies for identification of reportable disease and the mechanism for reporting to public health. All healthcare organizations have a role in the recognition of emerging infectious disease and bioterrorism events; an active infection surveillance program is a means of fulfilling that role (see also **119. Emergency Management**, and **120. Infectious Disease Disasters: Bioterrorism, Emerging Infections, and Pandemics**).

Intra-agency and Interagency Comparison of Infection Rates

Currently there is no national reporting system to compare infection rates for HHC. Many HHC agencies have infection surveillance programs, but there are few published reports of collaborative infection surveillance projects. One project allowing for interagency comparison of home care infection surveillance data has been facilitated by the MAHC. This project allows multiple agencies from several states, using standardized criteria and definitions, to compare catheter-associated UTI rates and central venous catheter infection rates.[49] Definition differences between HHC agencies and other organizations is an issue that needs to be resolved before a national surveillance system can be established.

OUTBREAK INVESTIGATION

Guidelines for outbreak investigation apply to all healthcare settings (see also **12. Outbreak Investigations**). The term "outbreak" refers to a frequency of healthcare events that greatly exceed the expected level. The term "outbreak" may also be applied to the occurrence of an unusual infection. There is no arbitrary number of cases that determines that an outbreak is occurring; even one case of a very unusual infection could constitute an outbreak. An outbreak may be the result of a single organism, single source, or single cause. Without baseline information that describes usual rates and typical organisms, an outbreak could go unnoticed. With an active infection surveillance program, unexpected increases in numbers or reports of an unusual infection are more likely to come to the attention of the home care IP. Because an outbreak may involve only a few cases, the HHC IP may be unsure if an outbreak is occurring. Recognition and investigation may reveal the cause of an outbreak, and additional infections may be prevented. Therefore, it is important that the HHC IP act on suspicion that an outbreak is occurring and begin a systematic and organized investigation.

EMERGENCY MANAGEMENT

As a service performed primarily in individual homes and the community, HHC agencies are essential to disaster preparedness and response efforts. HHC agencies already perform activities necessary for

effective emergency planning, such as assisting hospitals when at surge capacity, etc. During recent disasters, home care and hospice professionals were instrumental in caring for patients housed in shelters and nontraditional healthcare facilities.

Hospitals' first response to any type of disaster will be to discharge as many patients as possible; many of those patients will require ongoing medical care, and those duties may fall to HHC. Each HHC agency must have an emergency plan designed to coordinate its communications, resources and assets, staff responsibilities, utilities, and clinical and support activities during an emergency.[33,50,51] A patient priority classification system for patient evacuation, transport and supportive care, and use of staffing resources in an emergency/disaster situation should be developed.[51,52] >HHC agencies need to be involved with local and regional emergency management efforts. Many regions are making decisions that will affect home care (such as relying on HHC agencies to pick up the large number of patients discharged from hospitals and also planning to reassign home care nurses for placement in other settings) but are not including these professionals in the discussions (see also **119. Emergency Management**).

INFECTIOUS DISEASE DISASTERS: BIOTERRORISM, EMERGING INFECTIONS, AND PANDEMICS

In the event of an infectious disease disaster, the resources of HHC agencies will be overwhelmed. Planning for such a disaster is essential to ensure a sustainable healthcare response, and this plan may be incorporated into the emergency management plan.[53,54,55,56] When pandemic influenza is in the community, HHC agencies should contact patients and families before the home visit to determine whether anyone in the household has an influenza-like illness. If anyone does, then nonessential services planned for the visit home should be postponed. If this is not feasible, then consider assigning personnel who are not at increased risk for complication of pandemic influenza to care for these patients. It is important for personnel to wear appropriate respiratory protection to prevent infection transmission. The following environmental controls should also be considered when planning a scheduled visit to a patient in the home setting:

1. Open windows to increase air exchanges and dilute the concentration of organisms.
2. Place the patient in a separate room with door closed.
3. Minimize contact with others in the home.
4. Have patient follow respiratory hygiene and cough etiquette. Mask patient or at a minimum, cover cough with tissue or arm. Request patient perform frequent hand hygiene and place alcohol hand rub within reach of the patient (see also **120. Infectious Disease Disasters: Bioterrorism, Emerging Infections, and Pandemics**).

OCCUPATIONAL HEALTH

Although there is sparse published data about the risk of occupational-associated infections in HHC personnel, it is recognized that sharps injuries, exposures to blood and other body fluids, and exposures to communicable disease occur in all healthcare settings. In one study, 14 percent of registered nurses reported one or more percutaneous injury over a 3-year period. HHC agencies should provide education and safety needle devices to their employees.[56,57] HHC clinical staff should be provided only sharp safety devices (see also **100. Occupational Health**, and **101. Occupational Exposure to Bloodborne Pathogens**).

An effective occupational health program is essential in any healthcare organization. The occupational health program is considered within the overall structure of infection prevention because many

occupational health issues are also infection prevention issues. For example, appropriate immunization of HCP is not only important for the protection of HCP, it is also an essential intervention to reduce the risk of HAI.[58] TB prevention and control are important issues for both patients and HCP.[30] For these and other reasons, in many HHC organizations, responsibility for the design and management of the occupational health program falls within the domain of the IP. When the occupational health program is not included in the responsibilities of the IP, the IP should work collaboratively to design the infection prevention strategies of the occupational health program and work in close cooperation with the individuals who manage the occupational health program. Whatever the arrangements for providing the occupational health services, the HHC organization must ensure that there are arrangements for TB screening with appropriate follow-up for positive results, provision of recommended immunizations, health and safety education, surveillance for occupational exposures and job-related infection, and management of exposures to communicable disease. In addition, there must be policies for work restrictions for infected or exposed personnel, counseling services for personnel related to transmission risks for certain infections, and mechanisms in place to ensure the maintenance and confidentiality of personnel health records.[27,58]

THE ROLE OF THE INFECTION PREVENTIONIST IN HOME CARE

Many authorities and accrediting agencies require HHC agencies to assign responsibility for the infection prevention and control program to one or more individuals.[33] Although the activities of the IP are influenced by the size and structure of the organization, the areas in which the IP should have influence are consistent, including surveillance, policy and procedure development, consultation, education, performance improvement, and infection prevention activities. The responsibilities of the IP should include participation in the development of the policies and procedures related to infection prevention and control within the organization, including policies related to occupational health and safety. In the past, infection prevention in the HHC setting was often based on tradition or custom rather than evidence When developing infection prevention and control activities, the agency should use evidence-based national guidelines or, in the absence of such guidelines, expert consensus (e.g., clean versus sterile for chronic wounds),[59] or—in the absence of both—a review and evaluation of the healthcare literature.[33] In the last few years, national guidelines have included patient care across the continuum, including home care.[12,30,31,60]

When the HHC agency is affiliated with a hospital, there may be opportunity for a mentoring relationship between a hospital IP and the home care IP. More problematic is the situation in which infection prevention is one of many responsibilities assigned to one person. There are many educational resources available to the IP, including local hospital IP, the public health department, CDC, APIC, and the Community and Hospital Infection Control Association of Canada (see also **1. Infection Prevention and Control Programs**, and **2. Competency and Certification of Infection Preventionists**).

Reporting Structure

A determination must be made about the committee or group to which infection surveillance results are reported and by which decisions about interventions will be made. The name of this committee or group is not significant. What is significant is that the group be made up of leaders from the various disciplines within the organization. The multidisciplinary nature of the group is essential for collaboration in exploring contributing factors in the infection prevention concerns of the organization and when seeking solutions to problems that are identified through surveillance. Some organizations may choose to have a designated infection prevention committee; others may have infection prevention data reported to the

committee with performance improvement responsibility, risk management, or safety. When the HHC agency is a part of a hospital system, the home care infection prevention data may be reported to the committee where hospital infection prevention data is reported.

Education

It is the responsibility of the IP to ensure proper initial hire and ongoing staff education regarding infection prevention. Education should be provided on the topics of the signs and symptoms of infection, hand hygiene, waste management, bloodborne pathogens, safe sharps handling, infection prevention practices, recommended immunizations, and MDROs (see also **3. Education and Training**).

ACCREDITING AND REGULATORY AGENCIES

The Joint Commission

The Joint Commission provides accreditation standards and national patient safety goals for home care agencies in the United States. Currently there are accreditation standards for 16 functions, including chapters on infection prevention and control and emergency management. The infection and control standard includes identifying the agency risks for infection (patients and HCP), developing a plan to decrease infections, and implementing and evaluating the plan. The emergency management standard addresses the identification of potential hazards/emergencies that may occur and the development of plans for those emergencies using an all-hazards approach.[1]

Conclusions

The HHC setting is expanding, and the role of the IP will continue to be an important factor in improving patient outcomes. Cultural and societal changes coupled with limited resources will continue to drive the shift toward HHC as an essential alternative to acute or LTC settings. Although the emergence and growth of new technology (e.g., telemedicine) has already improved access to resources, the effect these advances will have on outcomes in HHC is still to be seen.

Future Trends

A national database for home care-associated infections is needed that would hopefully stimulate research to provide evidence-based best practice for home care.

Technology applicable to HHC is changing the way healthcare is provided. The effect of these devices and their role in infection prevention and patient safety requires further study.[2,22,24,47,51]

Caregivers in the home setting may be at risk for their health and safety; further study for recognition and interventions (e.g., respite) is required.[39]

International Perspective

Home settings vary around the globe. Although the delivery of care in the home setting may be considered a standard method in developed countries, the trend away from nonacute care settings in developed countries is still increasing. The IP should align preventive measures with the standard of

care in coordination with applicable regulations and guidelines based upon available resources (see also Supplemental Resources).

Supplemental Resources

American Academy of Home Care Physicians. Available at: **http://www.aahcp.org**.

Community Health Accreditation Program, Inc (CHAP). Available at: **http://www.chapinc.org**.

Engender Health, an international nonprofit Web site promoting the field of reproductive health, has free, basic online courses on infection prevention. Available at: **http://www.engenderhealth.org/**.

Missouri Alliance for Home Care. Available at: **http://www.homecaremissouri.org/**.

National Association for Home Care and Hospice (NAHC). Committed to representing the interests of the home care and hospice community. Available at: **http://www.nahc.org/**.

National Center for Infectious Disease, Centers for Disease Control. Healthy Pets, Healthy People website. Available at: **http://www.cdc.gov/healthypets/index.htm**.

National Institutes for Occupational Safety and Health (NIOSH). Preventing occupational exposures to antineoplastic and other hazardous drugs in health care settings. 2004 DHHS (NIOSH) Publication 2004–165. Available at: **http://www.cdc.gov/niosh**.

National Pressure Ulcer Advisory Panel (NPUAP). Available at: **http://www.npuap.org**.

World Health Organization (WHO). Observatory on Health Care for Chronic Conditions, Home-based long-term care: Available at: **http://www.who.int/chp/en/**.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Hospice and Palliative Care

Author(s): Doris Neumeyer, RN, BSN
Administrative Nurse Clinician

William Beaumont Hospital-Troy
Troy, MI

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Abstract

Although hospice care has been practiced for numerous years, recently there have been more published data available that specifically address infection prevention for the hospice or palliative patient population. Infection prevention for this unique set of patients requires a slightly different approach because of the different focus and objectives of this type of care. However, it is important to maintain basic infection prevention practices that pertain to all types of patient care, such as surveillance activities, prevention practices, Standard Precautions, sharps safety, safe handling of biohazardous materials, appropriate disposal of all waste (biohazardous, sharps, and regular waste), and healthcare personnel safety.

The concept of hospice care has been increasingly extended to patients who are not imminently terminal but who have a life-limiting disease (palliative care). Both types of care are provided in a variety of settings, including the patient's home, acute care facilities, and various other types of healthcare facilities across the continuum of care, as well as nonconventional settings such as jails and prisons. Further, the patient may move between these types of settings for care, which requires clear and effective communication between the different caregivers and healthcare personnel during the handoffs. This will ensure that the plan of care the patient desires is maintained.

Although the definitions of "hospice" and "palliative care" may differ, the intent is clearly the same: plan and provide care that supports the patient's goals, desires, and needs while managing the patient's pain and other symptoms as they progress through their disease process toward the end of life. It must be recognized in the planning of care that the patient is not going to recover from the major underlying illness. This differs from traditional medical care, in which the goal is recovery from the afflicting illness or the achievement of optimal levels of function. Infection prevention practices may need to be adapted so that the patient's requests, needs, and dignity are maintained and incorporated as safely as possible into the patient's plan of care.

Key Concepts

- Hospice and palliative care are similar in their intent but have distinct differences in their areas of focus.
- Hospice and palliative care both focus on managing the symptoms of the illness with an emphasis on controlling the discomfort and pain that a patient experiences while incorporating the spiritual, cultural, and religious needs of the patient and family or support system.
- Patient preferences, including spiritual, cultural, religious and personal needs and desires, are relevant to the care provided.
- Adaptations of treatments and care are fundamental to hospice and palliative care.
- Issues relevant to infection preventionists are similar to those identified in other healthcare settings and include selection, use, and disposal of personal protective equipment, cleaning of equipment, family and visitor education, risk assessment, hand hygiene, environmental cleaning and disinfection, surveillance (including syndromal), pet therapy and visitation, and quality and practice audits.
- Communicable disease and post-exposure follow-up necessitate close communication with public health.

Background

Hospice care as we know it has its roots in the mid-1960s. It was developed and molded by Dame Cicely Saunders, a physician from England, based on medieval practices for those who traveled long distances or were ill. Dame Saunders established the first modern inpatient hospice in a suburb of London in 1967.[1] At that time, the primary focus of hospice was on the terminally ill. "Hospice is a special concept of care designed to provide comfort and support to patients and their families when a life-limiting illness no longer responds to cure-oriented treatment."[2] Americans have increasingly become more interested in hospice care.[3] Individuals have a desire to have greater control over the type and method of medical care when a cure is not a realistic goal. With this interest, the principles of hospice have been expanded to include a broader group of patients with life-limiting illnesses and are now known more commonly as "palliative care." Palliative care is similar to hospice; with the defining difference being that with palliative care the patient's death is not expected to be in less than 6 months as it is in hospice care. Restrictions or limits on certain treatments by health insurers for patients enrolled in hospice programs may result in the patient deciding to delay or forgo enrollment into a hospice program so that they can continue with certain treatments. Although research studies have not been done extensively with this population, these patients are increasing and infection prevention principles can and should be applied using common-sense approaches.[4,5] Practices may need to be adapted to meet the desires of the hospice patient so that quality of life, autonomy, and spiritual and cultural needs are met. Communication is a critical component of care planning for this patient population. The potential risks need to be clearly explained and understood by the patient, caregivers, family, and significant others. Likewise, a clear understanding of the patient's desires and goals needs to be communicated to the healthcare team so the risks and benefits of infection prevention practices can be appropriately assessed and evaluated. Finally, communication between the various members of the healthcare team providing care in the varied settings needs to convey the plan of care that the patient has decided on, especially when the patient is no longer able to communicate on his or her own behalf. Then, appropriate and safe adaptations of infection prevention practices can be optimally made to ensure that the patient experiences the desired quality of life.

Basic Principles

The primary goals of hospice include the following:

- Managing pain and other symptoms
- Providing emotional support and spiritual comfort to the patient and family
- Permitting the patient to retain control over his or her life by adapting treatments, visitation, care, etc. wherever possible
- Supporting the family during the illness and bereavement period

BASICS OF HOSPICE AND PALLIATIVE CARE

The World Health Organization (WHO) defines palliative care as "an approach that improves the quality of life of patients and their families facing the problems associated with life-threatening illness, through the prevention and relief of suffering by means of early identification and impeccable assessment and treatment of pain and other problems, [including] physical, psychosocial and spiritual."[2] The Clinical Practice Guidelines for Palliative and Hospice Care developed and published by the National Hospice and Palliative Care Organization (NHPCO)[3] also include the term "debilitating illness" in its definition of palliative care. A search for research-based articles and information on infection prevention specifically for the hospice or palliative care patient has yielded a minimal number of studies. Of these, some were specific to certain diseases or did not address infection prevention issues that are unique to the hospice and palliative care patient. Hospice and palliative care both focus on managing the symptoms of the illness with an emphasis on controlling the discomfort and pain that a patient experiences while incorporating the spiritual, cultural, and religious needs of the patient and family or support system. Although the focus may not be on curing the patient, neither is it on attempting to hasten death. Rather, the focus is on collaboration with the patient and family through a difficult time that may be uncomfortable, stressful, possibly painful, and challenging in many ways, while maintaining the patient's quality of life, dignity, and desires in the plan of care.[3,6]

Hospice services are provided by an interdisciplinary team of trained professionals, including physicians, nurses, midlevel practitioners, dieticians, therapists, aides, social workers, case managers, chaplains, counselors, and volunteers who provide medical care and support services to the patient and family in the home and other care settings. The setting of care and level of hospice care received depends on the patient's condition and the needs and desires of the patient and family. The four basic levels of hospice care are as follows:

1. Routine home care
2. Respite care
3. Continuous care
4. General inpatient care

Routine home care services include periodic visits to the patient's place of residence by the members of the interdisciplinary team as required to meet the patient's and family's needs. Routine home care services may be provided in the patient's or family member's private residence or another care setting such as an assisted-living facility or skilled nursing facility.

Respite care may be provided when the patient's caregivers or family become fatigued and need a break. If the patient resides in a personal residence, the patient may be temporarily transferred to a

facility for up to 5 days and then transferred back home. By that time, the family is usually more rested and better prepared to meet the patient's care needs.

Continuous care may be provided if the patient's symptoms need additional management and cannot be controlled by routine home care services. Hospice may provide around-the-clock nursing services in the patient's place of residence. These continuous nursing services are based on patient and family needs and must be staffed by licensed nurses at least 50 percent of the time.

General inpatient care may be provided if the patient has pain or other symptoms that are not well controlled. Hospice may temporarily transfer the patient to an acute care hospital to aggressively manage the patient's symptoms and then transfer the patient back to the previous care setting. Sometimes it is the family's wishes that the patient not die at home. When the patient's death is imminent, the patient may be transferred to another care setting.

From an infection prevention perspective, it is the variation in the hospice care setting that presents the most significant challenge. The setting in which hospice care is provided affects the ability of the healthcare personnel (HCP) or caregiver to adapt infection prevention measures to meet the expressed desires of the patient; certain settings in which hospice care is provided may require adaptation of infection prevention measures. It is important that the patient's desires and goals be considered so that he or she maintains a desired quality of life.[3] Care settings can include the patient's personal home, hospital, assisted-living facility, long-term care facility, group boarding home, freestanding hospice facility, family member's home, and possibly jails and prisons. The setting should be assessed to determine what resources and infrastructures are available to provide care for the patient. The assessment data should be used to perform a risk assessment with the patient and family to determine what fits with the patient's desires and goals (see also **56. Home Care** and **61. Long-Term Care**).

INDIVIDUALIZATION OF THE PLAN OF CARE AND CULTURAL SENSITIVITY

The patient's individual spiritual, religious, cultural, and personal preferences should be incorporated when developing the plan of care.[3] Preferences of the patient should be taken into account when assessing for necessary infection prevention practices. A careful balance needs to be maintained between the patient's wishes and infection prevention practices to avoid unnecessary risk to the patient while still meeting the patient's desires. An example is adapting pet visitation so the patient can visit with and say good-bye to what may be the patient's closest friend.

Acute care and long-term care settings may present challenges in developing a plan of care that meets the patient's preferences. Every attempt should be made to incorporate the patient's preferences in his or her plan of care regardless of the setting. Although the patient may understand and accept the risk, the guiding principle should be that it does not cause harm or potential harm to other patients, caregivers, and HCP. Governing body regulations (i.e., from The Joint Commission, Center for Medicaid and Medicare Services, Healthcare Facilities Accreditation Program, Det Norske Veritas Healthcare Inc. [DNV], American Osteopathic Association, etc.) need to be followed and, if necessary, explained to the patient and his or her family.

Rituals are very important, whether tied to formal belief or just familiar to the patient. It should be recognized that the patient and the caregivers may need to follow certain rituals. Members of the healthcare team should understand how rituals may differ from culture to culture and religion to religion. The families or significant others involved with care of the patient may have their own views or perspectives as well, and these can affect the plan of care or how it is implemented.

PATIENT AND FAMILY EDUCATION

Education on infection prevention should be communicated to the patient, family, and caregivers in simple, clear terms with both the risks and benefits explained, so that the patient along with those the patient chooses can make the decisions that will let him or her maintain the quality of life and meet the expectations and goals they desire during this time. Research has not been done extensively on this patient population; general infection prevention principles and practices can and should be applied using common sense approaches. In some situations, practice and prevention measures may need to be adapted to meet the wishes of the patient to maintain the desired quality of life and autonomy.[3,5] The risk to the patient for infection or exposure should be minimized. The basics of infection prevention need to be taught to the caregivers, family members, and the patient. This includes the chain of infection transmission.[5]

The potential risks and benefits should be clearly explained and understood by everyone, including the patient, caregivers, family members, and/or significant others. This can be accomplished through open discussions and educational sessions on the risks and benefits for the patient, along with what can be done to minimize those risks (see **21. Risk Factors Facilitating Transmission of Infectious Agents**, **23. The Immunocompromised Host**, **27. Hand Hygiene**, **29. Isolation Precautions (Transmission-based Precautions)**, **30. Aseptic Technique**, and **122. Animals Visiting in Healthcare Facilities**). Likewise, the patient's desires, needs, and goals need to be clearly communicated to the healthcare team to be able to achieve the quality of life the patient desires. Basic infection prevention principles and practices can then be adapted to assist the patient in achieving the goals and desires while minimizing the risk for infection or exposure to the greatest extent possible.

STANDARD PRECAUTIONS, HAND HYGIENE, AND PERSONAL PROTECTIVE EQUIPMENT

Although there may be variation in the infection prevention perspective in hospice and palliative care settings, some infection prevention principles and practices remain the same. Hand hygiene is a basic, yet critical, component of infection prevention. Adherence to hand hygiene practices by HCP is essential. The patient, his or her family, and visitors need to be educated in proper hand hygiene practices and encouraged to follow them. Standard Precautions provide protections for both the patient and the HCP. Standard Precautions that protect the healthcare team must be followed regardless of the patient's desire and goals. It may need to be explained to the patient that these procedures are for the safety of the HCP.

Selection of personal protective equipment (PPE) for Standard Precautions can be made with consideration to protecting HCP and not the patient, if that is the patient's desire and he or she understands the risks. For example, a person with a respiratory infection does not necessarily need to be kept away from the patient to prevent transmission of the infection. If everyone understands the principles of infection prevention and the wishes of the patient, measures can be taken to significantly reduce the risk for infection to the patient while maintaining the quality of care the patient desires. Use of PPE (e.g., isolation masks) is only one method of infection prevention for respiratory infections; spatial distancing, use of facial tissues, and hand hygiene can also reduce the risk of transmission to an acceptable level while maintaining the quality of care and life the patient desires.

DEVICE UTILIZATION, SURVEILLANCE CULTURES, MULTIDRUG-RESISTANT ORGANISMS, AND ANTIBIOTIC USE

Device utilization in hospice and palliative care patients varies from central lines, feeding tubes, noninvasive respiratory aides, urinary catheterization, etc. Before a device is placed in a hospice/palliative care patient, the device and its purpose, care, benefits, risks, potential complications, and projected duration of use need to be openly discussed with the patient and incorporated into the plan of care if the patient agrees to the device. Some devices may be used for comfort measures (e.g., urinary catheter, so the patient can sleep through the night or conserve energy; central line for pain medications and/or other medications that reduce symptoms; antibiotics) in this patient population even though they may pose a risk to the patient. Care and maintenance of these devices should follow the established standard of care for the device. If the patient requests to not follow these standards, the healthcare team should seek alternative methods to care for the device that meet the patient's desires while providing optimal mitigation of infection and or adverse events.

There have been studies on the effect of screening and isolation for multdrug-resistant organisms (MDROs) in this patient population.[7,8,9,10] The findings of these studies indicate that screening and isolation for MDROs in a hospice and/or palliative care setting may not be as beneficial as in a hospital setting and may have an adverse impact on the patient. Screening for MDROs has not been demonstrated to be cost effective, nor has it significantly decreased the rate of healthcare-associated infections (HAIs).[7,8,9,10] Treatments for wounds and infections, especially MDROs, need to be discussed in depth with the patient and family members. Goals and objectives set by the patient need to be integrated into the treatment plan. Goals of the patient may emphasize comfort, drainage, and odor control, but not necessarily wound healing.[11,12]

In some cases the patient may decide to forgo treatment altogether. The use of antibiotics to treat infections in this patient population may be measured in terms of reduction of symptoms. Use of antibiotics for symptom control in this patient population is more effective for urinary tract infections.[13] The patient may desire to discontinue treatment of infections if the goal is symptom control and the symptoms are not resolving with the treatment.[11,12,13]

ENVIRONMENTAL CONCERNS

Environmental and equipment cleaning and disinfection may need to be adapted to the patient's resources and desires (e.g., cleaning and disinfection products used in the home may not be optimal but rather reflect what the patient can afford, has, and/or wants to use). Current cleaning and disinfection recommendations (see **21. Risk Factors Facilitating Transmission of Infectious Agents**, **27. Hand Hygiene**, **30. Aseptic Technique**, and **31. Cleaning, Disinfection, and Sterilization**) should be explained to the patient and family members and adhered to as much as possible. Those who prepare food for the hospice patient need to be knowledgeable about appropriate food handling techniques (see **109. Nutrition Services**). During end-of-life care, religious and cultural issues may become more evident and important to the patient. Caregivers, family members, and HCP should be aware of and understand the patient's beliefs and desires.

Handling and disposal of contaminated sharps and other medical waste must follow applicable local laws and regulations (see **21. Risk Factors Facilitating Transmission of Infectious Agents**, **29. Isolation Precautions (Transmission-based Precautions)**, **56. Home Care**, **105. Minimizing Exposure to Blood and Body Fluids**, and **113. Waste Management**).

SURVEILLANCE

Discussions with the patient and family members regarding strategies to reduce the risk of HAIs may be beneficial in reducing the risks and subsequent HAIs in the patient. These discussions should take place while setting goals and objectives with the patient and family. When an HAI has been identified, the circumstances surrounding the HAI need to be investigated to determine what the causative factor(s) were and what, if any, actions can be taken to prevent a recurrence.

The APIC–HICPAC surveillance definitions for Home Health and Hospice Care should be followed.[14] In most acute care health facilities, one or more diagnostic tests is part of the criteria for determining HAIs. In the home and/or home hospice settings, diagnostic testing is often not done. These settings require the IP to rely on clinical assessment and observation of the patient(s) by healthcare team members. An HAI identified in the home and/or home hospice setting does not necessarily indicate that it is the result of care provided. There are numerous environmental, physical, social, human, and other factors that the healthcare team has no control over in the home setting. Using the APIC–HICPAC surveillance definitions for home healthcare and home hospice infections, the IP can assess the care setting, establish a baseline rate, and establish target goals for HAI reduction.

Reportable communicable diseases must be reported to the appropriate local health authorities, regardless of the setting. This may be a challenge if diagnostic testing is not performed and is needed for reporting. Working with the local health authorities, a process should be developed to report suspected reportable communicable diseases without diagnostic tests.

Occupational health exposures and bloodborne and communicable disease exposures need to be monitored for healthcare team members in these settings, as definitive diagnostic testing of the patient may not be performed. CDC recommendations for immunizations for HCP need to be followed. This not only protects the HCP but also reduces the risk the patient will be exposed to a preventable communicable disease.

POSTMORTEM CARE

Cleaning and handling of the body postmortem may also be affected by the patient's and family's religious and cultural beliefs. It is best to discuss the patient's wishes prior to the patient's death. This will help avoid any conflict or controversy and will also ensure that rituals and practices are performed in a safe manner. Family members or caregivers may request to assist in preparing the body once the patient has expired. Some cultures and religions have specific practices that may put family members at an unnecessary risk unless appropriate PPE is used (see **65. Postmortem Care**).

In the event the patient has Creutzfeldt-Jakob disease (CJD), it is important to talk with the family to promote communication so that the emotional needs of the family, as well as the safety concerns of the funeral director and embalmers, can be accurately addressed. Specific information for families and caregivers of patients dealing with CJD is available through the NHPCO.[15]

Conclusions

Although it is important to maintain basic infection prevention practices while providing care for the hospice and palliative care patient population, the patient's and family's desires and needs should be taken into consideration when developing the plan of care and while providing care. Infection prevention may need to be adapted so that the patient's and family's requests, needs, and the patient's dignity are maintained and respected while safe care that is realistic for the patient's condition is administered. As

our population becomes more culturally diverse and integrated, the spiritual, religious, and cultural preferences of this population also should be studied.

Future Trends

Working toward seamless end-of-life care and use of electronic medical records to connect caregivers and support services continue to be two major areas requiring considerable work.

International Perspective

End-of-life care is affected by cultural elements and the diversities present in the populations. Therefore, the issues relative to care are guided by the individual society. Nevertheless, the principles of infection prevention are similar across all cultures, but the ability to consistently implement and evaluate deviation from accepted or ideal practice may vary because of cultural considerations. Political agendas and the construct of the healthcare system will also play a large role in how end-of-life care is supported.

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Imaging Services and Radiation Oncology

Author(s): Hong Kuan Kok, MB BCh BAO, BMedSci, MRCPI, MRCP(UK)
Department of Radiology

Tallaght Hospital
Dublin, Ireland

William C. Torreggiani, MB BCh BAO, MRCPI, FFRRCSI, FRCR
Department of Radiology

Tallaght Hospital
Dublin, Ireland

Deborah M. Nihill, RN, MSA, CIC, CPHQ
Director, Quality Management

Mercy Hospital
St. Louis. MO

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Abstract

Radiology departments, whether hospital-based or freestanding, encompass a wide range of specialized procedures and accommodate large, diverse patient populations. Advances in medical technology have paved the way for increasingly complex services involving both diagnostic and therapeutic aspects. Infection risks are patient- or procedure-related and range in severity from minimal with procedures performed on intact skin to high with invasive procedures. This creates unique challenges for the infection preventionist, who must assess the variety and scope of services provided by the radiology department.

Key Concepts

- Infection preventionists who are working or providing infection prevention oversight in radiology departments need to assess the potential infection issues relative to the services provided by the department and the patient population receiving services.

- Evaluation of the services provided in these areas should be considered during the infection prevention risk-assessment process.
- Radiology departments that see hospitalized inpatients and ambulatory outpatients need to consider the potential for disease transmission from infected patients to healthcare personnel, from infected/colonized patients to other patients, and from healthcare personnel to patients.
- The radiology department needs to establish good communication with patient care areas to ensure identification of patient isolation needs before patients are brought to the department.
- Strict adherence to aseptic technique must be observed for invasive procedures performed in the radiology department.

Background

Radiology departments face unique challenges, as the volume of patients seeking care has dramatically increased over the past several decades. Technological advances in diagnostic and treatment modalities along with insurance company pressures have contributed to increasing demands on radiology departments and the delivery of imaging services in an ambulatory care setting. In addition, advances in minimally invasive techniques have spawned a wide array of diagnostic and therapeutic procedures in radiology departments performed by interventional radiologists. The therapeutic use of ionizing radiation to treat cancers has also developed in parallel and both diagnostic radiology and radiation oncology now play a central role in the multidisciplinary management of cancer. Infection risks related to radiation services are generally patient- or procedure-related and range in severity from minimal with procedures performed on intact skin to high with invasive procedures.

Basic Principles

The surveillance, prevention, and control of infection cover a broad range of processes and activities, both in direct patient care and in patient care support, that need to be coordinated and carried out by the hospital.

Patients with an illness that can be spread by the airborne route (e.g., tuberculosis [TB]) should be screened and identified to the radiology department. Staff should recognize patient presentations that may put them at risk (e.g., patient with a cough) and be knowledgeable regarding appropriate infection control procedures, including isolation and barrier precautions. If patients are known to have an active infectious process, appropriate precautions should be performed with the use of personal protective equipment and discussion with the referring clinician to determine if testing or treatment should be delayed. However, this must be balanced against the clinical needs of the individual patient.

Environmental surfaces and equipment frequently become contaminated with microorganisms and can serve as an indirect source of transmission to patients, particularly in busy departments with a high patient turnaround rate. All healthcare personnel (HCP) should be instructed in proper hand hygiene procedures, and appropriate hand decontamination products need to be readily available for use.

HCP performing invasive procedures such as angiography are at risk for exposure to bloodborne pathogens via injuries from contaminated sharps and splashes (see **60. Interventional Radiology**). Patient-to-patient transmission of bloodborne disease has been observed during inadvertent injection of radioactive isotope-labeled blood products and reuse of syringes.

Imaging Services And Radiation Oncology

In diagnostic radiology, the scope of procedures performed range from basic radiographs to more complex studies such as ultrasound or computed tomography (CT) with varying patient contact times. Interventional radiology procedures are also performed with a combination of imaging modalities, typically ultrasound, fluoroscopy and CT, usually in a dedicated procedural suite. Many imaging studies involve the administration of contrast agents through an intravenous, enteral, or percutaneous route. Radiation oncology procedures are delivered in dedicated facilities with additional shielding to protect staff from the high levels of ionizing radiation involved.

EXAMPLES OF PROCEDURES:

1. Diagnostic radiography (e.g., chest or extremity radiography, mammogram)
2. Ultrasound (e.g., transabdominal, transvaginal, vascular)
3. Fluoroscopy (e.g., barium or contrast studies including swallow, enema, cystogram, intravenous urogram)
4. CT
5. Magnetic resonance imaging (MRI)
6. Interventional/invasive (e.g., angiography, percutaneous drainage of abscess, gastrostomy tube placement, vascular access, needle biopsies)
7. Nuclear medicine (e.g., isotope bone scan, renogram, white blood cell scan)
8. Radiation therapy (e.g., external beam radiotherapy, brachytherapy, CyberKnife, Gamma Knife, proton beam therapy, radioiodine thyroid ablation)

PATIENT- AND PROCEDURE-RELATED INFECTION ISSUES

Patients

Infection preventionists (IPs) providing coverage to radiology departments, including radiation oncology, need to assess the potential infection issues relative to the services provided by the department and the patient population receiving services.

Patient population characteristics include the inpatient/outpatient mix of patients receiving services. Radiology departments are often located in hospitals, but many are also freestanding centers, independent of the hospital. Radiology departments face unique challenges because the volume of patients seeking care has dramatically increased over the past several decades. Technological advances in diagnostic and treatment modalities along with insurance company pressures have contributed to increasing demands on radiology departments and the delivery of imaging services in an ambulatory care setting. Currently, 80 to 90 percent of all cancer care is delivered in the outpatient setting.[1] Patients with cancer undergoing therapeutic radiation treatments are often immunocompromised and are at risk of acquiring infections from the environment or other patients (see **23. The Immunocompromised Host**).

Radiology departments that see hospitalized inpatients and ambulatory outpatients need to consider the potential for disease transmission either from infected patients to HCP (e.g., patients being evaluated for *Mycobacterium tuberculosis*) or from infected/colonized patients to other patients (e.g., patients colonized/infected with methicillin-resistant *Staphylococcus aureus*). Patients thus can be either the source or the recipient of an infection. Infection prevention and control precautions, including isolation procedures, must be consistent in intent and application between inpatient and ambulatory care areas.

The surveillance, prevention, and control of infection cover a broad range of processes and activities, both in direct patient care and in patient care support, that need to be coordinated and carried out by the hospital. Isolation procedures must be able to follow the patient across the continuum of care and at the same time be appropriate for the environment.

Opportunities for Disease Transmission

Airborne

Waiting rooms and examination rooms are places where airborne diseases can be transmitted. Common waiting rooms often accommodate numerous patients at any given time. Most facilities do not have provisions for segregating potentially infectious patients from other patients in common waiting areas. Examination rooms are also potential places for airborne disease transmission, because patient volumes require rapid turnover of rooms, and room air is often recirculated throughout the department without filtration. In addition, because the diagnosis of acute respiratory illness is often confirmed through radiological investigations, sick patients are likely to be in common waiting rooms without proper isolation.

Airborne diseases of significance in the radiology department include TB (undiagnosed patient or diagnosed patient with suboptimal isolation precautions), severe acute respiratory syndrome, chickenpox, and measles.[2,3] Patients with an illness that can be spread by the airborne route should be screened first to determine if they need to be seen in the radiology department (clinically indicated testing that can be performed only in the radiology department versus portable examination that can be performed in the patient's room). If transport to the radiology department is necessary, patients are to wear a surgical mask for the entire visit, including transport to and from the department. Patients should also be instructed to cover the nose and mouth with a tissue when coughing or sneezing and to be separated as much as possible from other patients. Those with signs or symptoms suggestive of pulmonary TB should be evaluated promptly and not allowed to congregate in common waiting rooms.

Ideally, radiology departments where patients with TB are frequently treated should have an isolation area within the department that is equipped with negative-pressure ventilation. This may not be cost-effective for ambulatory settings, where such patients are infrequently seen. Additional engineering controls, such as a portable high-efficiency particulate air filter, may be needed to supplement the general ventilation in common-use areas. Department policy must also contain guidance regarding the use of respiratory protection for HCP and patients.

Certain times of the day may be reserved for accommodating patients with active TB to prevent exposing patients infected with human immunodeficiency virus or other immunocompromised persons to *M. tuberculosis*.[4,5]

The radiology department needs to establish good communications with patient care areas to ensure identification of patient isolation needs before patients are brought to the department. It is equally important to obtain needed information from referring physician offices and clinics. For other vaccine-preventable airborne diseases (e.g., varicella, measles, influenza, or rubella), immunization of HCP should minimize occupational exposure.

In addition, the Centers for Disease Control and Prevention's (CDC) "respiratory hygiene/cough etiquette" guidelines[6] provide guidance regarding activities that may decrease transmission of respiratory pathogens in ambulatory settings. Respiratory hygiene/cough etiquette includes the following:

1. Post visual alerts at the entrance to outpatient facilities instructing patients reporting for care to report respiratory symptoms.
2. Cover nose/mouth when coughing or sneezing. Cough or sneeze into your upper sleeve and not your hands.
3. Use tissues to contain respiratory secretions, and dispose of them in the nearest waste receptacle after use.
4. Perform hand hygiene after contact with respiratory secretions and contaminated objects/materials.
5. Provide tissues and no-touch receptacles for used tissue disposal.
6. Provide conveniently located hand hygiene agents (either waterless or soap/towels if sink is available).
7. Offer barrier masks to persons who are coughing.
8. Triage coughing individuals out of common waiting areas as soon as possible.

Contact

Environmental surfaces and equipment frequently become contaminated with microorganisms and can serve as an indirect source of transmission to patients. All HCP should be instructed in proper hand hygiene procedures, and appropriate hand decontamination products need to be readily available for use.[7] In addition, containment of patient secretions/excretions and appropriate environmental cleaning can reduce cross-transmission of these pathogens. Surfaces that come in direct contact with the patient should be covered (e.g., clean sheets or table paper) and/or cleaned and disinfected between patients. The surrounding area should be cleaned and disinfected regularly with an appropriate germicide (at the end of each day or more frequently if visibly soiled/contaminated). Easy access to environmental germicides is key to promoting environmental cleaning and disinfection because room turnaround times are frequently on a tight schedule.

Procedural Risks

Healthcare Personnel

HCP performing invasive procedures such as angiography are at risk for exposure to bloodborne pathogens via injuries from contaminated sharps.[8,9,10,11,12,13] Adherence to Standard Precautions is essential for all operators and is discussed in detail in the following chapter (see **60. Interventional Radiology**).

Patients

Patient-to-patient transmission of bloodborne disease has been observed during inadvertent injection of radioactive isotope-labeled blood products and reuse of syringes.[14] Meningitis after myelography has also been reported.[15] Strict adherence to aseptic technique must be observed for invasive procedures performed in the radiology department.

Medication Storage and Administration

Medications are often administered in the radiology department, particularly in interventional radiology and nuclear medicine. Multidose vials can be the source of medication contamination if there are breaches with aseptic technique and infection prevention.[16,17,18] Nuclear medicine procedures where material is removed from the patient, processed, and reinjected must include safeguards to ensure aseptic technique and proper identification and matching of the materials to the patient.[19]

Sharps Management

Injuries to HCP and the possibility of infection with microorganisms, especially bloodborne pathogens, can occur during percutaneous diagnostic or therapeutic procedures. Needles, guidewires, and other such sharps must be handled carefully to prevent inadvertent exposure of HCP to bloodborne pathogens.

Standard Precautions should be followed to prevent percutaneous and permucosal exposure to bloodborne pathogens during all patient care activities. Engineering controls, such as procedures to minimize handling of contaminated sharps, especially not recapping used sharps, and safety vascular access devices should be used. Contaminated and used syringes should be disposed of safely and appropriately. Puncture-resistant disposal containers for contaminated sharps should be conveniently located to encourage prompt disposal after use.[20] In the nuclear medicine department, where unsealed radioisotopes are used, engineering controls must emphasize the safe handling of the radiologic materials and contaminated sharps.

Cleaning, Disinfecting, and Sterilizing Equipment and Reusable Supplies

Cleaning, disinfection, and sterilization procedures are dictated by the intended use of the item. Cleaning precedes any further disinfection or sterilization (see also **31. Cleaning, Disinfection, and Sterilization**). Radiology equipment that comes in contact with intact patient skin requires low-level cleaning and disinfection. Equipment surfaces must be cleaned and disinfected after each examination.[21]

Facility-approved disinfectants should be conveniently located in close proximity to examination rooms for ease of use by department personnel. Attention should be paid to ensuring that disinfectants and other chemicals are located in areas where unmonitored access by patients and others (e.g., children) is avoided. Some equipment, such as mobile x-ray systems, are transported into hospitalized patient isolation rooms, and thus require disinfection before being transported to another patient room or returned to the radiology department. Disinfection processes should include all surfaces of the machine (except wheels). If other items, such as a film or computed radiography cassette, come into contact with the isolated patient, care must be taken to handle that item in a manner that prevents transmission (e.g., place in an isolation bag during transport and then disinfect as soon as possible).

The potential exists for procedure-related transmission of microorganisms if sonographic probes are not cleaned and disinfected between uses. Endocavitary ultrasound probes, including vaginal ultrasound probes, require cleaning and high-level disinfection between uses because of the contact with mucosal surfaces.[21,22] Use of condom-type covers is an important adjunct in preventing gross contamination of such items.[23]

Reusable equipment used for invasive sterile procedures must be cleaned and sterilized between uses.[22] Radiology departments located within hospitals often use the central processing department to perform sterilization services. However, some freestanding radiology centers perform their own sterilization using tabletop sterilizers. IPs should be aware of how sterilization procedures are performed and the training of the personnel performing the sterilization. Areas that perform sterilization procedures must have well-documented processes for training personnel and monitoring sterilization results (e.g., biological testing).

RADIATION ONCOLOGY SERVICES

Therapeutic uses of radiation have been in place since the early 1900s, with the science evolving since that time. Radiation oncology, the treatment of cancers using ionizing radiation, is a major therapeutic modality and encompasses a variety of procedures. Therapeutic radiation treatment can be used alone

or accompanied by systemic cytotoxic drugs or in combination with surgical procedures. Patients undergoing irradiation experience treatment-related side effects that vary in intensity based on many factors. The proportion of the body involved, the specific organs included, and the dose received determine the effects of radiation on the body.[24] Patient comorbidities such as hypertension or diabetes mellitus can also increase the risk of radiation toxicity.[25]

Radiation treatments cause a variety of local and systemic side effects that can predispose the patient to infection. Infection control issues are primarily related to treatment side effects.

Local Effects

The skin is the largest organ of the body and serves as a primary defense against infection by providing a physical barrier to the external environment. Fluid and electrolyte regulation and sensory and immune functions are also provided by the skin. Radiotherapy is most commonly delivered externally, and the patient's skin is therefore frequently affected by radiation treatments. Localized effects on the skin are generally radiation dose related and reflect changes in the cellular components of the epidermis, dermis, and vasculature.[26]

Recognized skin effects as a consequence of radiation treatment include erythema, vesiculation, desquamation, and hyperpigmentation.[26] Two additional phenomena may lead to skin changes and are known as radiation recall and radiation enhancement. Radiation recall occurs when patients who have previously received radiation treatment develop skin reactions at the irradiated treatment field, precipitated by the subsequent administration of chemotherapeutic drugs.[27] Radiation enhancement occurs when the intensity of the skin reaction to simultaneous administration of chemotherapy and radiation therapy is greater than that expected with radiation therapy alone due to radiosensitization.[28]

Skin reactions seen with radiation treatments are characterized as either early- or late-onset. Early-onset effects manifest during the course of therapy, whereas late-onset effects appear several weeks after treatment. Erythema (inflammation), pigmentation, epilation (loss of hair), dry desquamation (dry flaky skin), and moist desquamation (skin breakdown) are examples of irradiation-related skin effects seen during the treatment course. Skin folds such as the inframammary fold, axilla, and groin are especially prone to erythema and skin breakdown. The skin starts to heal during treatment, with the majority of healing taking place within 4 to 6 hours of treatment.

Late effects of irradiation include atrophy, fibrosis, xerosis (dry skin), hypopigmentation or hyperpigmentation, telangiectasia, and necrosis.[26,29] The degree of dermatitis is determined in large part by the amount of radiation used[30] (Table 58-1).

Table 58-1 Dermatitis by Dose of Radiation

Dose of Radiation	Damage	Cause
Low	Epidermal thinning	Decrease in mitotic rate of basal cell layer
Intermediate	Dry desquamation	Destruction of some of the basal cells
High	Moist desquamation, ulcers, necrosis	Severe dermal damage

Infection prevention measures are an integral part of the management of both early- and late treatment-related side effects on the skin. Goals of patient care and infection prevention are to promote and

maintain skin integrity, promote and maintain nutritional status, and protect from further irritation/injury.[24]

Severe skin breakdown results in loss of the defense barrier, exposing the patient to infection and also causing treatment delays due to the extra time required for healing. Recommendations for reducing damage to irradiated skin include minimizing mechanical (friction), chemical (soaps and detergents), and thermal (sun exposure) irritants.[31]

Systemic Effects

Systemic effects of radiation on the body are determined by the proportion of body area involved, the dose received, and the specific organs involved. The immunosuppressive effects of radiation therapy are well established with effects on both humoral and cell-mediated immune functions, particularly with large-field or total-body irradiation.[32,33,34]

Head and Neck Cancer

Significant oral and nutritional problems are reported in approximately 80 percent of patients undergoing radiation therapy for head and neck cancers. The cancers are often advanced when diagnosed and are complicated to treat because of the organs involved and functions found in the head and neck region. Mucositis, xerostomia (dry mouth), loss of taste, dental caries, osteoradionecrosis, and trismus are seen in this population. Oral mucositis occurring with irradiation to the head and neck is a major complication of cancer treatment.[35,36]Oral care and treatment guidelines have been developed for patients with oral and gastrointestinal mucositis.[37]Aspiration, leading to pneumonia, is a common complication (up to 68 percent of patients in one study) of combined chemoradiotherapy regimens.[36]

Bacteremia

Side effects of total-body irradiation combined with other cytotoxic medications include bacteremia (up to 30 percent in one study), diarrhea, and late varicella-zoster infection.[38]Bacteremia is a risk for patients treated for Hodgkin or non-Hodgkin lymphoma and may be treatment or disease related. Splenectomy or splenic irradiation increases the risk of life-threatening sepsis, especially with Gram-positive encapsulated organisms. Factors contributing to postsplenectomy sepsis include impaired humoral responsiveness, modified production of specific antibodies, and treatment- and disease-related immunologic changes. Pneumococcal vaccination and possibly *Haemophilus influenzae*vaccination may be recommended before the start of treatment.[39]

Radiation-Induced Colitis

Radiation directed at the colon generally induces mucosal inflammation and cellular damage.[40]

Maintenance of adequate hydration is important to prevent diarrhea-associated dehydration.

Pelvic Radiation Therapy

Effects on skin include skin breakdown in the perineal area because of location, local factors (increased warmth, moisture, lack of ventilation) and amounts of skin folds in the perineum with dry and wet desquamation seen. Estrogen derivation from high-dose pelvic irradiation causes mucosal atrophy and loss of epithelial lining of the vagina leading to vaginal infections. Organisms most commonly seen include *Candida*, *Trichomonas,*and *Gardnerella vaginalis*.

Brachytherapy

Brachytherapy uses catheter- or applicator-placed radioactive sources near to the tumor to deliver localized radiation for treatment. High-dose brachytherapy is associated with significant complications ranging from tissue irritation to ulceration and hemorrhage.[41]

Conclusions

In conclusion, the IP has multiple factors to consider when evaluating and planning an infection prevention and control program for radiology services. Having an understanding of pertinent patient and procedural risks will enable the IP to work with the imaging department personnel in designing an effective program. The IP should perform an initial detailed program and risk assessment that includes a site visit. Once high-risk areas and procedures are identified, a plan to monitor the department's compliance with appropriate infection prevention and control standards must be implemented. IPs need to reassess these program plans at least annually because services and populations may change and because of the need to provide guidance regarding programmatic and process improvements.

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Intensive Care

Author(s): Nancy Harless, MPH, BSN
IC Practitioner

Gaston Memorial Hospital
Gastonia, NC

Published: October 3, 2014

Abstract

Of all licensed hospital beds in the United States, only about 8 percent are intensive care unit beds.[1]

However, the prevalence of healthcare-associated infections has been reported to be much greater in critically ill patients than in the general hospital population.[2]*Hospitals, especially intensive care units,*

now deal with a cohort of patients who are most vulnerable to infection as a result of several factors, including advanced age, aggressive medical interventions, the shift to outpatient treatment, and improved survival of patients with underlying diseases, immunocompromised states, transplantation, and implanted foreign bodies. Risk factors for infection in the intensive care unit patient include impaired host defenses, extremes of age, and impaired nutritional status. Surveillance for healthcare-associated infections is an important element of an infection prevention and control program in the intensive care unit as an indicator of success.

Key Concepts

- Healthcare-associated infections lead to increased morbidity, mortality, cost, length of stay, and possible reimbursement penalties.
- Risk factors for infection in intensive care unit patients include impaired host defenses, extremes of age, nutritional status, and invasive therapeutic devices.
- Infection sites, incidence, and prevalence vary by intensive care unit type.
- The intensive care unit infection prevention and control program should include surveillance, use of standardized definitions, and actions to reduce patient risk.

Background

The 1996 Institute of Medicine report *To Err Is Human*defined healthcare-associated infections (HAIs) as preventable adverse health events. The Centers for Disease Control and Prevention's (CDC) National Healthcare Safety Network[3](NHSN) has been monitoring intensive care unit (ICU) site-specific, risk-adjusted infection rates by ICU type since 1987. NHSN data show that risk-adjusted infection rates have decreased in three body sites (respiratory tract, urinary tract, and bloodstream).[3]The pooled mean of central line-associated bloodstream infection (CLABSI) has decreased from 2.2 to 1.5 per 1,000 central line days.[3]This change may be due to definition changes, increased data from small hospitals that historically have less risk for infection, and/or an increase in effective quality improvement initiatives.[3]

In 2011, the NHSN experienced a 56 percent increase in the number of facilities reporting data. This increase is largely due to hospitals' participation in the Centers for Medicare & Medicaid Services (CMS) Hospital Inpatient Quality Reporting Program, which requires participants to use NHSN to submit mandated data. This mandated data in 2011 consisted of CLABSI rates in all adult, pediatric, and neonatal ICUs. Since that time, mandatory reporting has expanded to include catheter-associated urinary tract infections (CAUTIs) and certain surgical site infections (SSIs).[4]Using a process improvement approach and providing data for decision making, the quality of ICU care can be improve by changing behavior of patient caregivers.

Basic Principles

Our aging population, aggressive medical intervention, survival of patients with underlying diseases or immunocompromised states, transplantation, implanted foreign bodies, and the shift to outpatient treatment leave hospitals (in particular, the ICUs) with a cohort of patients that are most vulnerable to infection.

The ICU infection prevention and control program must be designed to identify and reduce the patient's risk for infection and adverse outcomes. The program should promote actions that are designed to limit the transmission or occurrence of HAIs. Surveillance for HAI is an important element of an infection prevention and control program in the ICU. Standardized definitions must be exact and applied consistently. To benchmark rates with other institutions, the same definitions must be used. In addition to obtaining numerators through the use of standard definitions of infection, device days are required for the denominator to provide the most meaningful data. NHSN data show that HAI surveillance combined with targeted interventions can reduce HAI rates, morbidity, and mortality and improve patient safety.[4]

Use of evidenced-based guidelines as shown by prospective observational studies can reduce rates of ICU infections, especially when tactics are bundled.

Infection sites, incidence, and prevalence vary by ICU type. In a burn unit, ventilator-associated pneumonia (VAP) accounts for the highest percentage of HAIs, followed by CLABSI.[5]*Staphylococcus aureus*is the most common cause of infection, followed by *Pseudomonas aeruginosa*. Pneumonia is the leading cause of HAI in medical-surgical ICUs.[6]More than half of all antibiotics prescribed in the ICU are for ICU-acquired pneumonia.[7]Pneumonia is also the most frequent infection in the neurology ICU, followed by urinary tract infection (UTI). In surgical ICUs, VAP is the most common HAI, followed by CAUTI.[5]Trauma units see almost half of their HAIs caused by pneumonia, followed by primary

bloodstream infections (19 percent), then UTIs and CLABSI (12 percent and 11 percent, respectively).[8]

See Table 59-1.

Table 59-1 . National Health Safety Network Report, Data Summary for 2011, Device-associated Module

Critical Care Unit	CLABSI Pooled Mean	UTI Pooled Mean	VAP Pooled Mean
Burn	3.7	4.1	4.9
Coronary	1.1	2.0	1.1
Surgical cardiothoracic	0.8	1.6	1.7
Medical, major teaching	1.2	2.6	1.1
Medical, all other	1.1	1.6	1.0
Medical/surgical major teaching	1.4	2.2	2.1
Medical/surgical all others	0.9	< 15 beds 1.2	1.1
		> 15 beds 1.4	1.0
Pediatric medical/surgical	1.8	3.1	1.1
Neurosurgical	1.0	4.5	2.3
Surgical, major teaching	1.2	2.6	2.4
Surgical, all other	1.0	2.0	2.0
	4.0	5.7	9.3

In surveillance, it is also important to be aware of device utilization, such as urinary and central venous catheters and mechanical ventilators. These invasive devices are an extrinsic risk factor for HAIs. Device utilization can also be a surrogate marker for severity of illness in patients, demonstrating their potential intrinsic risk to infection. Device utilization rate is specifically useful for measuring infection risk among ICU patients.

A device-associated infection rate is an example of a risk-adjusted infection rate and is usually expressed per 1,000 device days. Device utilization and device-associated infection rates are best evaluated together. For example, a high CLABSI rate may be found in one ICU with a higher central line utilization rate than in other ICUs in an organization. This would suggest that the higher use of central lines is contributing to the infection risk for CLABSI. Therefore, targeting efforts on reducing the use of central lines or limiting their duration would lower the risk for infection on this unit. If the ICU had a high device-associated infection rate with low device utilization, this would suggest infection prevention should focus on line insertion techniques and site and line care to reduce infection risk.

HAIs lead to increased morbidity and mortality.[8,9,10](See Table 59-2.) Infections involving the bloodstream and lung are an especially important cause of death. Although a crude rate of death does not separate the impact of a patient's comorbidities from the impact of the infection, the rate is significant. Crude mortality is the mortality rate from all causes of death for a population. The Surveillance and Control of Pathogens of Epidemiologic Importance system identified a crude death rate

of 27 percent for bloodstream infections (BSIs). Attributable mortality is defined as the direct contribution of HAIs to death after accounting for the impact of the underlying illness or comorbidities. Other studies have found the attributable mortality of BSIs to be 35 percent and for VAP 25 percent to 71 percent.[7,8,10] HAIs also prolong ICU and hospital stays. Other studies have that noted CLABSI can cost from $30,000 to $60,000.[1] Total annual costs for the five major HAIs (SSIs, VAP, CLABSI, *Clostridium difficile*, and CAUTI) was $9.8 billion.[11]

Table 59-2 Outcomes Based on Infection Status at ICU Admission and ICU-Acquired Infection

	No Infection at Admission and No ICU-Acquired Infection	Infection at Admission but No ICU-Acquired Infection	No Infection at Admission but ICU-Acquired Infection	Infection at Admission and ICU-Acquired Infection	*p*Value
Total TISS score*	170	197	324	668	< .001
LOS in ICU (days)	3	4	7.6	14	< .001
LOS in hospital (days)	17	16	18	31	< .001
ICU mortality (%)	2	5.8	8.6	8.9	< .43
Total hospital mortality (%)	6.1	17	9	35.6	< .002
Observed/predicted mortality†	0.15	0.35	0.75	0.70	

*TISS is therapeutic intensity score during entire ICU stay.
†Calculated according to APACHE II ICU admission.
From Ylipalosaari P, Ala-Kokko TI, Laurila J, et al. Intensive care acquired infection is an independent risk factor for hospital mortality: a prospective cohort study. *Crit Care*2006;10:R66.

ICU patients have more infection-related risk factors and have the highest infection rates, especially with multidrug-resistant organisms (MDRO). Risks include compromised host defenses, recent surgery, and use of invasive devices. Transmission of resistant strains is related to presence of vulnerable patients, use of antibiotics, and colonization pressure due to larger numbers of colonized patients.[12]

ICU patients with HAIs also require more ICU resources than do noninfected patients. Infected patients require more therapeutic intervention, such as dialysis, tracheostomy, and use of complex invasive devices that require skillful monitoring and manipulation. These invasive devices increase the number and duration of staff-patient contacts.

PREVENTING AND TREATING INFECTIONS IN THE INTENSIVE CARE UNIT

Risk Factors

Risk factors for infection in the ICU patient include impaired host defenses, extremes of age, and nutritional status.[13] Malnutrition is one of the most important factors for the development of HAIs.[3]

Malnourished ICU patients are 2.1 times more likely to be infected and also have longer total infection

times. Nutrition is further discussed later in this chapter. Hyponatremia is common in patients with pneumonia and is independently associated with increased use of mechanical ventilation and ICU resources.[14] Parenteral caloric supplementation is an independent risk factor for BSI in patients receiving total parenteral nutrition. This association is not related to hyperglycemia.[13]

The host may also have abnormal immune responses that are inherent, genetic, or acquired. Severity of illness or injury is also a risk factor for infection in ICUs. Many underlying diseases are associated with the risk for HAIs, including diabetes, cancer, renal failure, neutropenia, cirrhosis, altered consciousness, and impaired skin integrity.[13,15] ICUs outside industrialized nations continue to have higher rates of HAIs (see Table 59-3).

Table 59-3. Comparison of Device-Associated Infection Rates per 1,000 Device Days in ICUs of INICC (International Nosocomial Infection Control Consortium) and NHSN[16,17]

Table 59-3 Comparison of Device-Associated Infection Rates per 1,000 Device Days in ICUs of INICC (International Nosocomial Infection Control Consortium) and NHSN

Infection and Location	INICC Pooled Mean	NHSN Pooled Mean
Coronary ICU		
CLABSI	6.2	1.8
CAUTI	3.7	2.0
VAP	10.8	1.1
Medical-surgical ICU		
CLABSI	6.8	1.4
CAUTI	7.1	2.2
VAP	18.4	2.1
Pediatric ICU		
CLABSI	4.6	1.8
CAU	4.7	3.1
VAP	6.5	1.1

Thess data reflect information from 36 countries for January 2004 to December 2009. These countries include resource-rich and resource-poor nations.

INVASIVE DEVICES

In addition to impaired host defenses and severity of illness, invasive devices used therapeutically also increase the risk for infection in the patient. These devices break the integrity of skin and mucous membranes. Vascular devices, including hemodialysis, umbilical catheters, and central venous catheters (CVCs), are associated with greater risk of BSI than peripheral venous catheters.[12] CVC catheters can be inserted urgently when aseptic technique is not feasible, and this increases the risk for infection.

Vascular devices are often accessed multiple times per day, and each access poses a risk for potential contamination and infection.[18]

The use of the jugular vein rather than the femoral vein for short-term dialysis access did not reduce the risk for infection except in heavier adults according to Parienti.[19] The subclavian vein is not an option for patients requiring acute hemodialysis, because of the large size of the temporary dialysis catheters (Table 59-4). The catheter colonization was lower in the jugular catheters in patients with a body mass index greater than 28, though the jugular and femoral access groups had no statistical difference in incidence of CLABSI.[19] In hemodialysis patients with a history of recurrent *S. aureus*, CLABSI, povidone-iodine, or polysporin ointment should be applied to hemodialysis catheter insertion sites.[20]

Table 59-4 Contraindications for Use of Subclavian Site for Central Line Insertion

Infection over the insertion site
Distortion of landmarks from any reason
Suspected injury to the superior vena cava (e.g., SVC syndrome)
Pneumothorax or hemothorax on the contralateral side
Inability to tolerate pneumothorax on the ipsilateral side
Patients unable to tolerate Trendelenburg position
Prior injury to that vein (choose the one on the other side)
Morbid obesity
Recently discontinued subclavian catheter at the same location
Planned mastectomy on the side of subclavian insertion
Patients receiving ventilatory support with high end-expiratory pressures (temporarily reduce the pressures)
Patients with vigorous, ongoing cardiopulmonary resuscitation
Fracture or suspected fracture of ipsilateral upper ribs or clavicle
Children under 2 years of age (higher complication rates)

The left ventricular assist device (LVAD) is a surgically implanted mechanical device that helps the heart pump blood. Patients who require an LVAD fall into three groups: (1) patients waiting for a heart transplant; (2) patients who have had heart surgery but whose hearts cannot function and who use the LVAD until their heart function returns, usually in a few days; and (3) patients with severe heart failure in a clinical trial testing the LVAD as a permanent implant. The risks for infection and sepsis are important but are outweighed by the benefit of mechanical life-saving circulatory support. Clinical manifestations of LVAD infections vary based on the type of infection and the pathogen. Mortality is high despite various medical and surgical treatments.[21]

Concurrent chemoradiation (CCRT) is given preoperatively for eradication of micrometastasis, drug delivery through intact tumor blood vessels, and improvement of primary tumor resectablity.[22] Chen et al.[23] at Mackay Memorial Hospital in Taiwan, noted that CCRT is the standard postoperative adjuvant

treatment for high-risk rectal cancer patients. The addition of chemotherapy to radiation therapy increases the toxicity of treatment, particularly mucositis. Candidiasis is the most frequent opportunistic infection. Leukopenia and neutropenia occur in 30 percent of patients with infection occurring in 15 percent of those patients.[22]

Urinary catheters, including indwelling catheters, provide a continuous conduit for pathogens to access the urinary tract. More than 80 percent of UTIs are associated with indwelling urinary catheters.[24]

Prolonged use of the urinary catheter is the chief risk factor for infection.[25]

Mechanical ventilation is the main risk factor for development of VAP. The endotracheal (ET) tube is a conduit from the upper to the lower respiratory tract. Secretions collect around the cuff of the ET tube and may leak to the lower respiratory tract. This is the primary cause of lower respiratory infections.[26]It is important to ensure that all patients, unless contraindicated, are maintained in a semirecumbent position (30 to 45 degrees elevation). This elevation is a simple strategy to prevent aspiration. ICU beds should have a built-in tool for monitoring the angle of incline in mechanically ventilated patients. Studies have shown up to 67 percent reduction in VAP in patients who were maintained in a semi-recumbent position.[27]

Nasogastric tubes also contribute to infections such as sinusitis. Sinusitis is a common cause of fever in patients with either a nasogastric tube or a nasoendotracheal tube. Gastrostomy tubes can become colonized, leading to soft tissue infection at the insertion site. Feeding via the nasogastric route is also a risk factor for VAP, as it provides a fluid source for aspiration and microaspiration.[26]Placement of an external ventricular drain (EVD) is a common procedure to monitor intercranial pressure. These devices are associated with high rates of infection, up to 20 percent. Methods to reduce these infections include antimicrobial-coated catheters, prophylactic antibiotics, and catheter tunneling. Development of an EVD "bundle" is currently being researched.[28]

Therapeutic hypothermia has been shown to improve survival and neurological outcome following cardiac arrest. Patients with traumatic brain injury and ischemic stroke also have had positive response to therapeutic hypothermia. Cooling may be induced by surface cooling, endovascular cooling catheter, and cold infusion. Possible side effects include infection, hemorrhage, and change in water and electrolyte levels.[29]Risk for infection for induced hypothermia is similar to the risk for infection resulting from perioperative hypothermia. A core body temperature between 34°C and 36°C during surgery triples the incidence of postoperative wound infection.[30]

There has been an overall decrease in device-related HAIs. One action that has contributed to this improvement is the use of "bundles" for device insertion and care. These bundles represent evidence-based practices shown to result in positive outcomes. They include the factors described below.

CLABSI: Elements of the insertion bundle include as outlined by the IHI:

- Hand hygiene for all providers
- Maximal barrier precautions for inserter and patient
- Chlorhexidine skin antisepsis
- Optimal catheter site selection
- Daily review of line necessity for the line

CAUTI: Bundles for CAUTI prevention have been developed by individual facilities, but most contain the following elements for insertion and maintenance:

Insertion

- Assess catheter necessity
- Clean the urethral meatus prior to catheter insertion
- Use a single-use packet of lubricant
- Aseptic insertion technique
- Catheter secured
- Sterile closed drainage system

Maintenance

- Daily assessment of catheter necessity
- Catheter secured
- Tamper-evident seal intact
- Drain tubing is properly positioned and secured (no dependent loops)
- Drain bag properly positioned (below bladder and not touching floor)
- Drain bag is not overfilled
- At least daily catheter hygiene

VAP: Bundles for prevention of VAP include:

- Head of the bed 30 degrees
- Daily sedation vacation and daily assessment of readiness to extubate
- Peptic ulcer disease (PUD) prophylaxis
- Deep vein thrombosis (DVT) prophylaxis
- Daily oral care with chlorhexidine

SSI: Measures to prevent SSI come in large from the Surgical Care Improvement Project (SCIP) protocols, a national quality partnership of organizations interested in improving surgical care by significantly reducing surgical complications and include:

- Prophylactic antibiotic received within 1 hour prior to surgical incision
- Prophylactic antibiotic selection for surgical patients
- Prophylactic antibiotics discontinued within 24 hours after surgery
- Surgery patients with appropriate hair removal
- Urinary catheter removed on postoperative day 1 (POD 1) or day 2
- Surgery patients with perioperative temperature management

TRANSMISSION AND MULTIDRUG-RESISTANT ORGANISMS

Many events contribute to the evolution from colonization to infection. When designing infection prevention strategies, it is important to understand the different transmission routes to interrupt cross-transmission. For example, healthcare personnel (HCP) risk cross-contamination when not complying

with appropriate hand disinfection guidelines while caring for multiple body sites in the same patient. Colonization with *S. aureus*or methicillin-resistant *S. aureus* (MRSA) is common in both healthy and hospitalized individuals; it most often involves the anterior nares and is frequently asymptomatic. Colonization increases risk of infection. Patient-to-patient transmission of MRSA within healthcare settings primarily occurs via the hands of >HCP.[31]The continued emergence of MDROs remains a concern in ICUs.[32,33,34,35]It is well accepted that MDROs resemble an iceberg, with the identified infections representing only a portion of unidentified or colonized patients. Emergence of MDRO is facilitated by failures of hand hygiene practice, selective pressure by overused antibiotics, and bacterial genetic mutations. Antibiotic-resistant strains may also enter the ICU through transfer of patients, contaminated equipment or environment or colonized HCP. These bacteria can be disseminated through failures in infection prevention practices. Bacteria can achieve resistance to antibiotics in two ways: inherently or through spontaneous gene mutation or transfer of genetic material from other bacteria. Once acquired, the resistance genes are transmitted by reproduction. Since bacteria reproduce rapidly, it takes only a short time for an entire population of bacteria to become resistant to an antibiotic.[36]

Over the past decade, there has been increasing evidence that contaminated environmental surfaces in hospital rooms play an important role in the transmission of pathogens, including MRSA, vancomycin-resistant enterococcus (VRE), *C. difficile, Acinetobacter,*and norovirus.

*Acinetobacter*commonly colonizes patients in the intensive care setting. *Acinetobacter*colonization is particularly common in patients who are intubated and in those who have multiple intravenous lines or monitoring devices, surgical drains, or indwelling urinary catheters. Perencevich et al.[30]noted higher rates of Gram-negative infection during the summer months. For each 10°F increase, they observed a 17 percent increase in the monthly rates of infection caused by *P. aeruginosa*and *A. baumannii*. These findings suggest that for infection prevention, enhanced surveillance during the warmer months for *Pseudomonas*and *Acinetobacter*may be warranted.[30]A seven-bed trauma ICU in an orthopedic hospital in Greece experienced an outbreak of imipenem-resistant *A. baumannii*sepsis. Contaminated environmental surfaces and patient care equipment and transiently colonized hands of HCP were the sources of transmission. To eradicate the outbreak, the ICU was closed and decontaminated and hand hygiene was reinforced.[37]

The mechanisms of MDROs are complex. MRSA, VRE, extended-spectrum β-lactamase *Klebsiella pneumoniae*, and inducible-lactamase *P. aeruginosa*are commonly seen in ICUs.[38]From 1990 to 1997, the prevalence of VRE in hospitalized patients increased from less than 1 percent to approximately 15 percent. VRE accounted for almost 25 percent of *Enterococcus* isolates in ICUs in 1999 and 28.5 percent in 2003.[39]

Surveillance studies have demonstrated the trend toward ICU patients with MDRO.[40]The spectrum and incidence of MDRO infections have increased steadily.[40,41]Approximately 16 percent of all HAIs reported in NHSN were multidrug-resistant pathogens.[16]Compared to historical NNIS reports, the NHSN update on antimicrobial resistance 2006–2007 report found a slightly lower resistance percentage among device-associated HAIs for MRSA and for extended-spectrum cephalosporin-resistant *P. aeruginosa*but higher resistance percentages for VRE and extended-spectrum cephalosporin-resistant *Escherichia coli*.[16]

Colonization is the presence of microorganisms that are not causing clinical signs or symptoms of infection. Colonization precedes HAI in most cases. Exceptions are direct inoculation through contaminated fluids, such as intravenous fluids, injectable medication, or blood. Recent studies have shown that 8.5 to 29 percent of patients colonized with MRSA progressed to infection, with the median time from positive screening culture to infection being 9 days. Steroid therapy prior to admission and development of pressure ulcers after admission were found to be independent risk factors for progression to infection.[42] Active surveillance testing is an effective method to identify MRSA colonization among patients admitted to the ICU. Ridenour et al.[34] found that 11 percent of ICU admissions were colonized with MRSA, and 22.8 percent of all bed care days were dedicated to MRSA-positive patients. Colonization precedes infection in these patients. Immunodeficiency, severity of illness, and exposure to the hospital environment contribute to the patient's colonization with hospital flora.

Infection preventionist (IP) consultation on unit or facility design can also affect the transmission of pathogens and subsequent HAI. Hota et al.[43] reported an ICU outbreak of multidrug-resistant *P. aeruginosa* related to the ICU sinks used for hand washing in a Toronto, Ontario, hospital. The sink drain contents splashed at least a meter from the sink, contaminating the surrounding areas. The outbreak was terminated only when the sinks were renovated to prevent such splashing. The outbreak organism contributed to or directly caused the death in 71 percent of the patients who died within 3 months of the outbreak.[43]

C. difficile infection (CDI) severity has been increasing and is associated with increased length of stay. The epidemiology of CDI has changed in recent years, with an increase in incidence and virulence internationally accompanied by an increase in attributable mortality. Early identification of patients who have or are suspected to have CDI is the imperative to control possible transmission. Compliance with Contact Precautions and personal protective equipment (PPE) help to break the chain of infection. *The APIC Guide to the Elimination of Clostridium difficile in Healthcare Settings* is a source for understanding transmission, surveillance, and prevention measures.[44] Research shows evidence of the role of contaminated environmental surfaces in the transmission of CDI. Being admitted to a room previously occupied by a patient with CDI has been shown to be an independent risk factor for the development of CDI. Prevention measures include decreased use of medications known to predispose to CDI, use of Contact Precautions with soap and water, hand hygiene, and enhanced environmental cleaning with sporicidal agents.

The incidence of *Candida* spp. as HAIs has increased. A study at a major university hospital revealed a 3 percent increase since 1980.[45] *Candida* and other yeasts are the fourth most frequent healthcare-associated pathogen.[43] *C. albicans* is the most frequently isolated fungal species in all sites.[38] The assessment and diagnosis of invasive candidiasis are difficult in nonblood cultures, and as a result antifungal therapy may be delayed. Delay in antifungal treatment is associated with significant attributable mortality. ICU patients at highest risk include burn or trauma, cardiac surgery, oncology, general surgery, and high-risk neonate patients. Risk factors for fungal infection include previous use of antibiotics, mechanical ventilation, urgent surgical procedures, use of corticosteroids, and APACHE IV score. Prevention, diagnosis, and treatment of *Candida* infection remain challenging. Antifungal treatment is often prescribed empirically in the presence of worsening patient condition without explanation.[38]

Carbapenem-resistant Enterobacteriaceae (CRE) are a relatively new serious threat to patients. Infections with CRE are difficult, and in some cases impossible, to treat and have been associated with

mortality rates up to 50 percent. Due to the rapid emergence of this resistant pathogen, the CDC has released a CRE toolkit available at **http://www.cdc.gov/hai/organisms/cre/cre-toolkit/index.html**. This site continues to be updated as new information is gathered.

Data regarding the frequency of resistant organisms has been gathered by the NHSN. From January 2009 through December 2010, 69,475 HAIs were reported from 2,039 hospitals. Roughly 65 percent of these infections were from critical care areas. The degree of resistance did not significantly differ among types of critical care units. The main resistant organisms were:

- MRSA
- VRE
- Multidrug-resistant *Klebsiella pneumoniae/oxytoca*
- Multidrug-resistant *E. coli*

TRANSMISSION-BASED PRECAUTIONS

Consistent use of Standard Precautions for all patients and Transmission-based Precautions for patients with known infections is recommended to reduce cross-transmission of pathogens in the ICU.[46] Use of Standard Precautions is the primary strategy for the prevention of healthcare-associated transmission of pathogens among patients and HCP. Three new elements of Standard Precautions are respiratory hygiene, safe injection practices, and specific PPE requirements for lumbar puncture procedures.

STAFFING

Studies have shown that increased registered nurse staffing and subsequent lower nurse-to-patient ratio was associated with less hospital-related mortality, failure to rescue, cardiac arrest, hospital-acquired pneumonia, and other adverse events.[47]

Sentinel events are unanticipated events that result in death, injury, or permanent loss of function.[46]

Other studies have also found a relationship between nurse staffing and outcomes in medical patients, including incidence of UTI, pneumonia, and length of stay.[41,48,49,50] Lower nurse-to-patient ratios are associated with an increase in late-onset VAP in ICUs. Studies show that more than 20 percent of all-site ICU-acquired infections could be prevented if the daily nurse-to-patient ratio (total number of nurses working per day/patient census for that day) is maintained above 2.2.[51] More investigation is required to determine whether other variables, such as registered nurse experience or use of temporary workers (contract and float pool), contribute to the adverse outcome. A recent study does show an association between nurse workload, nurse burnout, and increases in both urinary tract and surgical site infections.[52] Although IPs may not influence ICU staffing levels, during low staffing the IP may increase ICU rounds and stress adherence to best prevention practices such as hand hygiene and Transmission-based Precautions.

LENGTH OF STAY

ICU patients are at higher risk for development of infection or colonization due to prolonged length of stay as well as many other factors.[46] Physician-led multidisciplinary rounds, daily meetings to assess bed utilization, use of bundles, and culture changes focusing on team decision-making processes decrease ICU length of stay and reduce cost of ICU episodes of care.[53]

NUTRITION

It is generally accepted that malnutrition is a risk factor for HAI. Body weight is not a good measure of nutrition in a critically ill patient because many are overhydrated and show a weight increase. Serum albumin is not a good indicator of nutritional status but is a predictor of patient outcome. Low-serum albumin correlates with an increased incidence of medical complications.[54] Prealbumin is, however, an independent predictor of mortality and morbidity. Prealbumin is used to diagnose protein-calorie malnutrition. In this condition, the body breaks down muscle, protein, and body fat. Prealbumin levels in infected patients are significantly lower than in normal patients without infection.[54] Prealbumin changes more quickly than albumin, which makes it more useful for detecting changes in short-term nutritional status.

More investigation is needed to develop simple and effective criteria to identify patients with poor nutritional status and to profile the patient who would benefit from immunonutrition. An example of immunonutrition is enteral feeding after liver transplantation. Bacterial infections frequently occur early after liver transplantation. Early enteral nutrition supplemented with a mixture of lactic acid bacteria and fiber reduced infection rate by 48 percent.[55]

Several studies in the past decade demonstrated improved outcome in ICU patients managed with strict glycemic control. The effect of these studies has been a change in the treatment of acute hyperglycemia in ICUs. Strict glycemic control has become a perceived standard of care in critical care.[56]

It is hypothesized that probiotics, nonpathogenic bacteria, could restore gastrointestinal flora that have been altered by antimicrobial therapy, thus protecting the patient from colonization or overgrowth of *C. difficile*. Results from studies are mixed, and to date there are not enough evidence-based data to support this intervention as a best practice.[44]

HCP Vaccination

Vaccination of HCP is an important element of patient safety. This is especially true of seasonal influenza vaccination, as this has been shown to be the most effective strategy to prevent spread in healthcare settings. Patients cared for in ICU settings are high risk and are likely to experience increased morbidity and mortality if infected with influenza.[39]

PREVENTION

Antimicrobial coated or impregnated invasive devices have been shown to reduce the incidence of HAIs. Silver is effective as an antimicrobial agent in the treatment of burns and pressure ulcers. Silver ions have a broad-spectrum activity against numerous organisms. Several studies have shown a decrease in CAUTI and bacteriuria when using silver alloy-coated urinary catheters.[57] Venous catheters impregnated with minocycline and rifampin and those impregnated or coated with chlorhexidine and silver sulfadiazine have been shown to decrease CLABSIs.

Technology, however, cannot substitute for sound core system processes designed to minimize the risk for HAIs. For example, although an impregnated catheter can help reduce risk for infection, it alone cannot overcome poor care processes. Site selection, skin preparation, maximal barrier precautions

during insertion, and appropriate site care remain critical core processes to reduce infection in the ICU patient with a CVC. Independent risk factors for CLABSI related to line insertion are femoral catheterization, internal jugular catheterization, prolonged duration of catheterization, and heavy microbial colonization at the insertion site.[18,20]

Inappropriate use of antibiotics leads to increases in morbidity, mortality, and development of MDROs. An antimicrobial stewardship program is an effective method of dealing with these issues. Such a program includes limiting inappropriate use and optimizing selection, dosing, route, and duration of therapy for antibiotics. Audits of antibiotic use should be prospective, with direct feedback to the prescriber.[58]

Conclusions

Infection preventionists can be instrumental partners with the ICU care providers in determining a set of indicators for infection prevention surveillance and intervention. In this partnership, IPs can help guide the development of case-finding and scrutinize each case against a standard definition. Using a process improvement approach and providing data for decision making, the quality of ICU care can be improved by changing the behavior and practices of patient caregivers. The IP can provide information, education, and intervention tools to the ICU to reduce host risk factors for infection. Through targeted surveillance and intervention, the IP can assist the ICU care providers in reducing infection rates and influencing morbidity, mortality, cost of care, and length of stay. ICUs across the United States have demonstrated it is possible to achieve zero HAIs.

Supplemental Resources

Association for Professionals in Infection Control and Epidemiology (APIC). Available at: **http://www.apic.org**.

Guidelines tab has surveillance, prevention and elimination documents. Available at: **http://www.apic.org/Professional-Practice/Scientific-guidelines**

Centers for Disease Control and Prevention (CDC). Available at: **http://www.cdc.gov**.

Compendium of Strategies to Prevent Healthcare-Associated Infections in Acute Care Hospitals. *Infect Control Hosp Epidemiol*2008;29(suppl 1):S31–S40.

National Guideline Clearinghouse. Available at: **http://www.guideline.gov/**.

World Health Organization (WHO). *WHO guidelines on hand hygiene in health care.*2009. Available at: **http://www.who.int/gpsc/5may/tools/9789241597906/en/**.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Interventional Radiology

Author(s): Hong Kuan Kok, MB BCh BAO, BMedSci, MRCPI, MRCP(UK)
Department of Radiology

Tallaght Hospital
Dublin, Ireland

Darragh Halpenny, MB BCh BAO, MRCPI, FFRRCSI
Department of Radiology

Tallaght Hospital
Dublin, Ireland

William C. Torreggiani, MB BCh BAO, MRCPI, FFRRCSI, FRCR
Department of Radiology

Tallaght Hospital
Dublin, Ireland

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Abstract

Interventional radiology techniques are used to treat a wide variety of diseases in a minimally invasive fashion. Although the risk of infection during these procedures is generally reduced when compared with their surgical equivalents, the potential for infectious complications is ever-present in the intervention room. As the specialty has developed, increasing emphasis has been placed on the importance of infection prevention. To this end, improved sterile technique in the periprocedure period, purpose-built interventional departments modeled on the operating room, prophylactic antibiotics for interventional procedures, the widespread adoption of universal precautions, and improved interventional technology have all enhanced infection prevention concepts and practices in this field. This chapter contains a detailed discussion of these topics, and provides information on the infectious complications of specific interventional techniques.

Key Concepts

- Interventional radiology is a rapidly growing specialty in which minimally invasive techniques are used to treat a variety of benign and malignant conditions under radiological guidance.
- An appropriately designed and staffed intervention room is vital for adequate infection prevention.
- Full surgical asepsis should be adhered to during most interventional procedures.
- Standard Precautions for interventional staff reduce the risk of transmission of bloodborne infections.
- Antibiotic prophylaxis reduces infective risk in many interventional procedures.
- Certain interventional techniques have a high risk of infective complications, and particular vigilance is required when performing these procedures.

Background

The field of interventional radiology encompasses a broad range of both diagnostic and therapeutic techniques. Although there has always been a procedural based element to the speciality of radiology, the concept of interventional radiology only truly developed in the 1960s. Since then, the number and scope of interventional procedures has increased hugely, to the point where the interventionalist now has the ability to treat many conditions previously only manageable with invasive surgical techniques.

The term *interventional radiology*was officially used for the first time in 1967. In the decade that followed a growing number of centers described their experience of using radiological techniques to guide invasive procedures. What began with a physician pioneering a novel radiological technique rapidly evolved into a new specialty. Initially, the work being performed was purely vascular in nature, and to date this is still the largest subsection of work performed in the intervention room. However, as the field developed, it expanded to involve the treatment of gastrointestinal, hepatobiliary, neurological, pulmonary, and genitourinary diseases.[1]

One of the advantages of interventional radiology over a more invasive surgical procedure is the reduced risk of infection, which stems from the use of a smaller access point to the body.[2]However, by its very nature, interventional radiology breaks the natural defense of the patient's skin. Although minimized, the potential for infection is thus an ever present threat in the intervention room both in the acute setting, immediately postprocedure, and in the longer term, particularly when foreign material is left in the patient. Without proper awareness, the risk of infection can be high in busy radiology departments, where the increased demand for interventional services has led to rapidly escalating patient throughput. Allied to this is the fact that many of the patients treated in the intervention room have comorbidities and are thus at increased risk from infectious complications. The changing mandate of radiologists coupled with the above information has driven a new approach to infection prevention in the interventional room. Increasingly a more "surgical" attitude has been adopted as departments have striven to reduce the infectious complications of interventional procedures.

Basic Principles

The list of conditions that are now amenable to interventional treatment continues to grow. Although vascular interventional radiology remains the largest subspecialty within the field, there is virtually no organ system that is not accessible using interventional methods. Although the full list of interventional procedures is large, there are certain techniques that underpin much of what is done in the intervention room. The scope of this chapter is not to provide a detailed explanation of every possible procedure.

Rather, an overview of the basic techniques involved is provided, with, in some cases, specific examples of common procedures to illustrate certain points regarding infection prevention. The following can be regarded as the fundamental techniques of interventional radiology and are elaborated on in the following discussion:

- Angiography
- Angioplasty
- Endoluminal stenting
- Embolization
- Inferior vena cava (IVC) filter placement and removal
- Central venous access
- Drainage procedures
- Image-guided biopsy

Basic Knowledge

LABORATORY SETTING

The interventional radiology suite is located within the radiology department. The layout of a typical interventional room has evolved from being a variation on a traditional diagnostic radiology room, to one having the ability to meet the demands of a 21st century interventional radiology service. Several commentators have proposed guidelines for the design of the interventional department, aimed at increasing efficiency and reducing infectious complications.[3,4]

As with most aspects of interventional radiology, the trend has been toward adopting similar standards as the surgical operating room. As far as is practicable, a one-way system of patient and staff movement should be adopted within the interventional area. If possible, several different entrances should be provided. One entrance is for patients alone, which can be further divided into an area for ambulatory and nonambulatory patients if space allows. A separate staff entrance should be connected with any changing facilities that are provided, whereas a final entrance is needed for sterile material.

Ideally, two actual procedural rooms would be provided: one for nonsterile procedures such as drain insertion and the other room for sterile procedures such as central venous catheter insertion. The size of the room should be at least 400 square feet; and, in some cases, particularly if the room is to function as a specialized suite for endovascular stenting, commentators have suggested a minimum size of 600 square feet.[3,4]

The surfaces in the intervention room, including electrical cables, should be smooth to allow easy cleaning and disinfection according to hospital-approved or manufacturers' recommendations. This includes the provision of seamless floors. False ceilings should not be used because of their propensity to accumulate dust. Any ceiling material should be readily washable. In terms of the air quality, again, similar standards to those used in the operating room should be employed. Positive pressure should exist in the intervention room and the air should be renewed by filter between 20 and 35 times per hour. The ambient air should have a temperature of 20°C (68°F) to 25°C (73°F) and a humidity of 20 to 60 percent.[5,6]The Centers for Medicaid & Medicare Services (CMS) has modified their requirements to allow for the 20 percent lower limit effective June 2013.[7]In addition to the actual

intervention room, adjoining rooms should allow waiting areas for both inpatients and outpatients. If anesthetic facilities are available, an anesthetic preparation room and a recovery area are needed. Finally, a soiled utility room adjacent to the intervention room where contaminated material can be stored is important to allow the controlled disposal of waste material. In practice, the provision of the layout described in the preceding is not always possible, particularly in non–purpose-built facilities where space may be at a premium.

STAFFING

The interventional radiology room is generally staffed by radiologists (usually a primary operator and an assistant), anesthetists, nursing staff, radiographic technicians, and orderlies. In some specialized endovascular suites surgical teams may also have input into certain cases.

STANDARD PRECAUTIONS

One aspect of the gradual change in attitudes toward infection prevention that has brought interventionists more in line with their surgical colleagues is the increased adherence to the concept of Standard Precautions in the intervention room. The Centers for Disease Control and Prevention (CDC) advocates the use of Standard Precautions in any setting in which exposure to contaminated bodily fluid may occur. This means the use of eye protection, facemask, gloves, and nonpenetrable gowns is recommended in such situations.[8] Thus, from the inside out, the interventional operator should wear a surgical scrub suit, a lead coat with a minimum of 0.5 mm lead, and a sterile surgical tunic that is changed between cases. In addition, a surgical cap, shoes, facemask, and eye protection should be worn. As well as providing protection from contaminated fluid, the eye protection should be lead lined (see **28. Standard Precautions**).

Even when Standard Precautions are adopted in the interventional room, continued vigilance is required. Glove perforations, although less common than seen in surgical procedures, are well recognized in interventional radiology with gross perforation rates of up to 5 percent and occult perforation rates up to 1 percent reported.[9] The rate of perforation increases with duration of use, thus the routine changing of gloves in a prolonged procedure should be considered. Although the use of routine double-glove technique is questionable, it is certainly recommended for high-risk cases.

PROCEDURAL PREPARATION

Most interventional techniques are performed using a conscious sedation technique. In some institutions, anesthetic support is available for major interventional cases.

Preparation of the patient's skin prior to surgery with clipping for hair removal has been shown to reduce postoperative infections and it is suggested that similar standards be applied to interventional cases. It is recommended that hair be removed on the day of the procedure at a location away from the treatment area. In the case of inpatients this should be done on the ward, whereas outpatients should be prepared in the radiology department.[3]

A surgical hand-washing technique should be adopted for interventional procedures. Clearly, the standard of hand-washing facilities is paramount. Automatic controls and elbow-operated liquid disinfectant dispensers should be found over a deep trough, over which the hands are cleaned.

Hand hygiene procedures vary from institution to institution. The following guidelines are adapted from the CDC's *Guidelines for Hand Hygiene in Healthcare Settings*:

1. Jewelry should be limited. If worn, rings, watches, and bracelets should be removed prior to hand washing.
2. The subungual area should be cleaned with a nail cleaner under running water.
3. Either an antimicrobial soap or an alcohol-based hand rub with persistent activity should be used.
4. For use of an antimicrobial soap, wash for 2 to 6 minutes; longer can damage skin.
5. For alcohol-based agents, the hands should be prewashed and thoroughly dried. After use of alcohol rub, the hand should be dry before gloves are donned.
6. The arms should be cleaned to the elbow.

Technicians and nursing staff can use a routine hand-washing technique between patients.[10](See **27. Hand Hygiene**, and **68 Surgical Services**.)

The classification of surgical procedures into categories based on their infective potential has been applied to interventional procedures and has implications for the planning of an interventional list.[11]

Procedures are classified into clean, clean-contaminated, contaminated, and dirty based on the wound classification system of the American College of Surgeons which was adapted by the CDC National Healthcare Safety Network, corresponding to approximate infective risks of up to 5, 11, 17, and over 27 percent, respectively although more recent data suggest that infection rates may be lower than previously reported.[12]A procedure is clean if sterile precautions are maintained, there is no obvious inflammation, and the gastrointestinal, respiratory, or genitourinary tract is not entered. A clean-contaminated procedure involves entry into one of these systems, but without evidence of overt infection. Contaminated procedures involve a major loss of sterile technique or work in an area of obvious inflammation, but without frank pus. Finally, a dirty procedure essentially involves working in an area of abscess formation, or in an infected biliary tree.[13]If the facilities are available, clean procedures should be performed in a separate room from contaminated procedures. Similarly, if patients are known to be infected or colonized with healthcare-associated agents such as methicillin-resistant *Staphylococcus aureus*(MRSA), *Clostridium difficile*, vancomycin-resistant enterococci (VRE), or extended-spectrum beta-lactamase (ESBL)-producing organisms, a system of communication between the wards and the interventional room must exist to allow such procedures to be performed last on a list (see **29. Isolation Precautions (Transmission-based Precautions)**).

The interventional room should be cleaned after each procedure. Surfaces that are routinely disinfected include the operating table, radiographic controls, x-ray housing, lead shields, and the floor adjacent to the operating table. At the end of each operating day when the interventional room has been used, terminal cleaning should be performed to minimize the degree of environmental contaminants by microorganisms, dirt, and dust.[11]This process should start at the highest level from the ceiling and lighting fixtures to all room equipment and progress to ground level fixtures and the floor using appropriate disinfectant solutions (see **31. Cleaning, Disinfection, and Sterilization**).

Infectious Complications Of Interventional Radiology Procedures

VASCULAR INTERVENTIONAL RADIOLOGY

Central Venous Catheters

Insertion of a central venous catheter allows medium or long-term venous access to be maintained in patients in whom peripheral venous access is not sufficient. Common indications for such catheters in the radiology department include patients receiving chemotherapy, dialysis, total parenteral nutrition, or long-term antibiotics. Infection is the most common serious complication of central venous catheter insertion.

During insertion the right side of the neck is preferentially used for access, because of the more direct access to the superior vena cava (SVC) and right atrium (RA). The internal jugular vein is the most commonly accessed vein. Ultrasound is generally used to guide the initial venous puncture. A micropuncture technique using a 21G needle and guidewire is the safest technique to access the vein. A 4 French sheath is then placed to maintain access, while an extra stiff guidewire is passed, under fluoroscopic guidance, into the IVC. The venous puncture is then dilated to the appropriate size, over the guidewire, and a larger venous sheath is left in the vein. At this stage the tunnel for the line is created, if one is required, using blunt dissection and a trocar. Once passed through the tunnel, the catheter is inserted into the venous sheath and thus into the internal jugular vein and SVC.

Catheter-related infections (CRIs) are seen in between 3.3 and 4.4 percent of patients with central venous ports and catheters but may be even higher, up to 22.5 percent, in patients with long-term cuffed and tunnelled central venous catheters.[14] The pathogenesis of infection depends on the type of catheter and method of insertion, but in most centrally placed catheters, infection results from the contamination of the catheter hub. Infrequently, hematogenous spread or contaminated infusions can also cause infection.[15]

Several factors affect the rate of CRIs. Besides the internal jugular route, subclavian and femoral sites are the next most frequently used. Femoral catheters have the highest rate of infective complication. When compared with the subclavian approach, a jugular catheter is associated with higher number of CRIs. However, the technical difficulty and potential for other complications, such as pneumothorax, when using a subclavian approach must be weighed against the benefit of reduced infections.[16] The material from which the catheter is manufactured influences the long-term risk of infection. Polyurethane catheters treated with oligon (polyurethane combined with silver, carbon, and platinum) appear to reduce colonization rates compared with nontreated catheters.[17] As would be expected, the use of maximal sterile precautions, including formal surgical scrub technique and draping, has been shown to reduce the risk of infection significantly, whereas more recently the use of antimicrobial-impregnated catheters has proved an independent factor in reducing infection rate.[18] Catheters coated with antimicrobial agents in this manner are now widely available. These devices are predominantly externally coated, but some incorporate a coating on the intraluminal surface. Chlorhexidine, silver sulfadiazine, minocycline, and rifampin are the most frequently used agents, mainly used in combination. Chlorhexidine and silver sulfadiazine in combination reduced rates of colonization and infection but only in the short term. They appear to be a cost-effective way of reducing CRIs in a patient population with short-term catheters if the rate of infection exceeds 3.3 per 1,000 catheter days after bundled standard procedures have been implemented (e.g., educating personnel, using maximal sterile barrier precautions at insertion, and using >0.5 percent chlorhexidine preparation with alcohol for skin antisepsis).[15,19] Newer catheters with an additional intraluminal coating that allows an extended release of chlorhexidine from the extraluminal surface seem to offer improved resistance to CRIs, at least in the short term.[20] Minocycline and rifampin provide the alternative combination of antimicrobial agents for catheter coating. These agents are used both intraluminally and extraluminally. They provide a better broad spectrum of activity when compared with chlorhexidine and silver sulfadiazine catheters and also reduce the number of CRIs. When

compared with the alternative combination of antimicrobials, a CRI is 1/12th as likely with minocycline/rifampin.[21] In contrast to the chlorhexidine and silver sulfadiazine group, the cost effectiveness of these catheters only becomes apparent after catheters have been inserted for more than 2 weeks.[22,23]

Skin preparation for catheter placement should be performed with an antiseptic solution based on 70 percent alcohol, tincture of iodine, and iodophor or chlorhexidine gluconate.[15] An antiseptic preparation containing >0.5 percent chlorhexidine and alcohol is preferred prior to central venous catheter insertion as it is associated with lower rates of catheter colonization but iodine-based or 70 percent alcohol preparations can be used as alternatives if there is a contraindication to chlorhexidine.[15,15] Combination skin disinfection with chlorhexidine, propanol, and povidone-iodine has been shown to be superior to any single agent alone although this combination is not routinely recommended in present guidelines.[24]

In a review of the factors associated with an increased rate of CRI, the following have been shown to result in more frequent infection:[25]

- Heavy colonization of the insertion site
- Contamination of the catheter hub
- An inexperienced operator
- Jugular placement (rather than subclavian placement)
- The use of guidewire exchange through an old catheter to place a new one

Conversely, factors associated with a reduced risk of CRI were found to be:

- Formal training in catheter placement
- Maximal sterile barrier precautions at placement
- Chlorhexidine-based skin preparation
- Use of catheters with an anti-infective surface

Regarding catheter replacement strategies, the routine replacement of catheters as a method of preventing infection is not known to work. When a catheter must be replaced in the setting of a proven or suspected CRI, a guidewire should not be used to insert the new catheter via the old one.[15] In certain groups in whom vascular access is difficult, exchange of an infected hemodialysis catheter via guidewire may be performed within 72 hours of initiating antimicrobial therapy and with antibiotics continued for 3 weeks.[26]

The organisms responsible for CRI are predominantly those found as normal skin flora. The most common causative organisms are coagulase-negative staphylococci, accounting for 37 percent of CRIs. *Staphylococcus aureus*, enterococcus, and Gram-negative rods and *Candida*species all account for a significant minority of the total number of CRIs. In line with known trends, the percentage of resistant strains is increasing. The debate is ongoing in many institutions regarding the most appropriate department in which to routinely insert long-term catheters. Those inserted in the intensive care unit are associated with a higher rate of infections than catheters placed radiologically or surgically. Few studies have directly compared the intervention room and the operating room as the location for catheter insertion. However, when they have been compared in the adult setting, a significantly higher rate of

infection in surgically placed catheters has been found. The explanation for this discrepancy is not clear, but may relate to increased local trauma and tissue dissection, which can predispose to infection.[27] In a pediatric population, similar results have been obtained, with a lower rate of infection seen in radiologically placed catheters and comparable mechanical failure rates demonstrated among groups.[28]

The CDC issued recommendations in 2011 regarding central venous catheter insertion to minimize the risk of CRI. In summary, they are:

- The use of catheters with the minimum number of ports and lumens essential for the patient.
- The use of totally implantable devices for long-term use.
- The use of a subclavian access site for nontunneled catheters is preferable for infection prevention, but must be weighed against the potential for mechanical complication.
- Hemodialysis catheters should use the jugular or femoral route to reduce the risk of venous stenosis.
- Use a fistula or graft in patients with chronic renal failure but, if this is not feasible, a tunnelled cuffed-catheter should be used.
- Use ultrasound guidance to place central venous catheters (if available) to reduce the number of cannulation attempts and mechanical complications. Ultrasound guidance should only be used by those fully trained in its technique.
- Maximal barrier precautions should be used and include the use of a cap, mask, sterile gown, sterile gloves, and a sterile full body drape.
- A .0.5 percent chlorhexidine preparation with alcohol is the preferred antiseptic for skin preparation.
- Antimicrobial and antiseptic impregnated catheters should only be used for long-term catheters when other anti-infective strategies have been implemented and have failed.
- A catheter should not be removed based on a fever alone.
- Routine replacement of catheters to prevent infection is not necessary.
- Guidewire replacement should not be used for replacement of an infected catheter.

Angiography

Angiography is widely practiced in interventional radiology, both for diagnosis and as a prelude to treatment. The subject of infection prevention in the setting of angiography has been comprehensively dealt with elsewhere in this volume. The following section deals with a selection of more complex endovascular techniques that use angiography as a starting point.

Percutaneous Endoluminal Stenting

The infective complications of cardiac stent placement have been extensively discussed elsewhere in this volume. There are several other percutaneous arterial stenting techniques that are, in the main, performed in the interventional radiology suite. The most common sites for the placement of such stents are the aorta, iliac, femoral, popliteal, renal, carotid, and subclavian arteries. There are reports of stent infections in all of these locations.[29] The overall rate of endovascular stent infection is 0.37 percent.[30]

This seems to compare favorably with the rate of infection for open vascular surgery, which can be as high as 1.3 percent. The debate regarding the most appropriate location for graft insertion is ongoing. Some studies have demonstrated a higher infection rate for endovascular procedures performed in an interventional room rather than an operating room. The need for an optimal sterile environment has led commentators to propose that such procedures should be performed endovascularly in the operating

room rather than the interventional room.[4] This approach gives the added advantage of immediate surgical backup if needed for what can often be complex cases. The disadvantage to this approach is that, in practice, most operating rooms are ill equipped for nuanced radiological studies and are lacking in stringent radiation protection techniques. The solution may be the creation of a dedicated hybrid endovascular suite combining the advantages of the interventional and operating rooms. The following have been proposed as some of the requisite specifications for a dedicated endovascular suite.[3,4,5,6,7]

- High resolution ceiling-mounted imaging equipment, rather than the portable devices often found in operating rooms
- Nonmetallic, carbon fiber surgical table
- Adequate lighting
- Full complement of operating room, interventional room, and anesthetic personnel as required
- Immediate access to all surgical trays and equipment
- Immediate access to all angiographic and interventional catheters
- Integrated scheduling of all surgical, radiological, and anesthetic personnel
- Twenty to 25 air exchanges per hour
- Positive air pressure in the endovascular suite
- Ambient air temperature of 20°C (68°F) to 25°C (73°F)
- Humidity of 20 to 60 percent
- Washable ceilings to prevent dust contamination
- Seamless floors for ease of sterilization
- Adequate traffic control procedures
- Minimum size of 400 to 600 square feet

The mechanism of infection in the setting of endovascular stenting may lie in the unavoidable splitting of the intima and media during angioplasty and stent deployment. This may provide a mechanism for bacteria, which are either exogenously introduced or which lie within the plaque itself, to cause infection.[31] Additionally, Paget et al. demonstrated in their seminal study that the risk of infection decreases after 3 months following stent deployment in an animal model, likely a result of endoluminal reendothelialization and mural incorporation of the stent.[32] Risk factors predisposing to infective complications include concurrent central venous catheter infection, immunosuppression, multiple endovascular procedures, and pseudoaneurysm repair.[30]

The clinical manifestations of stent infection are varied. The mean lapse of time from graft insertion to development of symptoms is 6 weeks. Patients may simply initially present with vague symptoms related to chronic inflammation. However, the clinical manifestations frequently progress to become more dramatic. Common presentations include retroperitoneal abscess formation, aortoenteric fistula, inguinal fistula, septic emboli, and hemorrhagic shock. The sequela of infection can be devastating. Approximately three-fourths of patients require surgical intervention, and the mortality rate can be as high as 27 percent.[30]

The most commonly isolated organism in cases of stent infection is *S. aureus*, which accounts for 50 percent of the total infective complications and almost three-fourths of early infections. Enterococcus

and *Escherichia coli* are the next most common, accounting for 9 and 7 percent of infections, respectively. Because of the low incidence of infection, the routine use of prophylactic antibiotics is usually not warranted. For those patients at high risk of infection (as discussed), administration of cefazolin 1 g intravenously can be considered.[33] Vancomycin or clindamycin can be used in the setting of penicillin allergy. In addition, many operators routinely administer prophylactic antibiotics to patients undergoing aortic endograft placement.[29] As a general rule regarding antibiotic prophylaxis in interventional procedures, antibiotic coverage should be given within 1 hour of the procedure to ensure therapeutic level of drug during the intervention. In practice, the best way to ensure this is to administer antibiotics in the intervention department.

EMBOLIZATION

The embolization of an organ or part of an organ is a well-established technique for treating a variety of benign and malignant disease. The arterial system is accessed in the same manner as described in another chapter (see **34. Intravascular Device Infection**) regarding angiography. An aortogram is performed and the appropriate end artery is selected using a guidewire and a selective catheter. Once the catheter is in the correct position, the appropriate embolization material, mixed with iodinated contrast, is instilled under fluoroscopic guidance. The most common embolization materials are particles, coils, foam, glue, and ethanol, whereas doxorubicin, mitomycin, and cisplatin are the most commonly used chemotherapeutic agents for transarterial chemoembolization (TACE) procedures. The most common sites for solid organ embolization are the liver, kidneys, and uterus. Embolization by its nature results in an area of necrotic tissue, which may act as infective nidus and the infective risks of embolization procedures are well described.

Transarterial Chemoembolization

TACE is an interventional technique predominantly used for the treatment of inoperable hepatocellular carcinoma or liver metastases. Hepatic necrosis and abscess formation are infrequent complications of this procedure. However, when they do occur, the sequelae can be devastating.

The primary mechanism for infection appears to be contamination of the embolized segment of hepatic parenchyma with organisms from the biliary tree. Cultured organisms are frequently enteric in origin and biliary disruption from ischemic injury or previous intervention as well as central necrosis within the embolized tumor with superimposed bacterial seeding has been associated with abscess formation.[34,35]

Theoretically, the damage to the biliary tree occurs if there is reduced blood flow in the larger hepatic arteries during embolization causing radiological contrast and chemoembolic agents to be diverted to the peribiliary capillaries. This results in local toxicity and ultimately bile duct damage. The single biggest risk factor predisposing to abscess formation is previous bile duct surgical or radiological intervention. The disruption of blood flow to the biliary system associated with such biliary surgery is likely to be aggravated by embolization of the hepatobiliary vasculature as described, thus predisposing to bile duct damage postembolization.[34,36] Abscess formation is rare (<1 percent) in the absence of predisposing factors; however, the presence of a bilioenteric anastomosis, compromised sphincter of Oddi from sphincterotomy, or biliary stent increases the risk by 30-fold.[36]

A triad of fever, chills, and right upper quadrant pain are the most likely presenting symptoms. A complicating factor is that these symptoms are frequently present in the normal postembolization patient. Persistence of symptoms for 1 week should raise suspicion. In addition, vigilance must be maintained for up to 3 months posttreatment.[37] There is wide variety in the reported time frame for development of

abscess post procedure. In the literature, time to development of abscess varies from the first week up to 4 weeks or later post-TACE.[36] The relative rarity of infection is likely caused by the judicious use of prophylactic antibiotic therapy in these patients. As with other potentially contaminated procedures, antibiotics should be commenced prior to the procedure and is recommended by the Society of Interventional Radiology (SIR).[31] Some authors advocate a 7-day course of treatment. Standard antibiotic prophylaxis varies between centers both in length of treatment and antimicrobial choice. Reported regimes include ampicillin/sulbactam, cefazolin/metronidazole, or ceftriaxone preprocedure followed by the same combination until discharge with amoxicillin/clavulanate for 5 days post discharge.[33,38]

The frequency of infection in patients with an abnormal biliary system has led investigators to assess the use of more aggressive antimicrobial prophylaxis in this subset of patients. Two small series have examined this problem. Patel et al. began treatment with levofloxacin 500 mg once daily and metronidazole 500 mg twice daily 2 days before embolization, continued until 2 weeks after discharge.[37] A bowel preparation of neomycin and erythromycin was also given. Although their study was small, there was a trend toward reduced rate of abscess formation.[35] Geschwind et al. compared a more aggressive regime of piperacillin/tazobactam intravenously 36 hours prior to embolization plus bowel preparation with neomycin and erythromycin with a standard regimen of cephalexin. Again, this was a small study, but a reduced rate of infection was demonstrated in the experimental group.[39] Although not statistically significant, these results certainly seem to indicate that a more intense antibiotic regimen should be considered in high-risk patients.

Uterine Fibroid Embolization

First initiated in the mid-1990s, uterine fibroid embolization (UFE) has become widely accepted as an effective alternative to hysterectomy or myomectomy for treatment of symptomatic fibroids. Complications are rare and postembolization infection even less so. The reported infectious complication rate in the larger case series is 1.2 percent, specifically referring to intrauterine infections rather than urinary tract infections.[40,41] Although rare, the sequelae of infection can be serious. There are occasional reports of sepsis-related mortality after UFE. In cases of intrauterine infection, hysterectomy may ultimately be necessary as the definitive treatment.

Attempts have been made to identify risk factors associated with development of intrauterine infection. The presence of submucosal fibroids appears to confer a higher infective risk when compared with patients with nonsubmucosal fibroids alone.[40] Fibroid size has also been postulated as a potential determinant of infective risk. There are case reports of large fibroids requiring treatment for infective complications postembolization. The largest study to examine this phenomenon, however, found no definite link between fibroid size and uterine infection.[42] Presentation with infectious complications occurs relatively late, usually at approximately 2 weeks post procedure. Fever, pelvic pain, and vaginal discharge are common presenting complaints. Skin pathogens are the most common causative organisms. Both *Staphylococcus* and *Streptococcus* have been cultured from patients with sepsis in the aftermath of UFE.[29]

Although the use of prophylactic antibiotics is widespread, several studies have demonstrated that evidence for their use is inconclusive.[29,40] Some groups have recommended that because of the delayed nature of infection in these patients, antibiotics should not be given at the time of the procedure,[29]

whereas others have postulated that antibiotic use in this setting can even be counterproductive, particularly if multiple drugs are used. This effect is believed to stem from the fact that combinations of antimicrobials at the time of the procedure may allow the proliferation of pathogenic organisms in the place of normal flora. Nonetheless, single agent prophylaxis is common and routine prophylaxis is recommended by the SIR with a cephalosporin such as cefazolin being the most frequent choice. Alternatives include ampicillin/sulbactam or vancomycin for penicillin-allergic patients.[33]

Transjugular Intrahepatic Portosystemic Shunting

Transjugular intrahepatic portosystemic shunting (TIPS) has become an established treatment for cirrhotic patients with uncontrollable variceal hemorrhage or refractory ascites. This percutaneous procedure creates an intrahepatic shunt between a branch of the portal vein and the systemic circulation. Patients undergoing TIPS are generally acutely unwell and frequently suffer from multiorgan failure. The risk of infection in patients with advanced cirrhosis has been shown to be in the order of 30 to 35 percent.[43,44]In addition, infection is often poorly tolerated in this immunocompromised group.

The right internal jugular vein is accessed in a similar manner to that described to begin a central venous catheter placement. Once the venous system has been accessed, the right hepatic vein is preferentially selected. A special TIPS needle, consisting of a curved inner needle and an outer catheter, is then inserted into the hepatic vein. To identify the portal vein, fluoroscopy alone is generally used, although other methods, including ultrasound, can be employed. The needle tip is turned anteromedially and advanced caudally out of the hepatic vein approximately 5 cm. When the portal system is entered, a guidewire is passed into the mesenteric vein. The tract is dilated using a balloon catheter. Once dilated, a bridging stent, often partially covered with polytetrafluoroethylene, can be deployed. After deployment, if the portal varices remain full, they may be selectively embolized. If the portal pressures remain high, a second parallel stent may be inserted using a separate hepatic vein.[45]

Periprocedure pyrexia without frank sepsis has been recognized in up to 10 percent of patients post-TIPS, whereas post-TIPS bacteremia has been documented in up to 35 percent of patients.[46]Postulated causes for this phenomenon include the seeding of mesenteric bacteria into the systemic circulation and an inflammatory reaction in the liver following stent placement.[47]The incidence of sustained bacteremia, involving infection of the stent and resulting in sepsis, is significantly lower and has been estimated at approximately 1.7 percent.[48]The etiology of this type of infection is unclear. They may be associated with thrombus or vegetation formation within the stent, although a definitive link of this finding with infection has not been established.[48]Patients receiving multiple stents and those with central venous catheters in situ appear to be at higher risk of developing infection as demonstrated in a seminal randomized trial by Deibert et al.[49]Consideration should be given to removal of central venous catheters that are not absolutely necessary following completion of a TIPS procedure.

A wide variety of organisms have been implicated in post TIPS infections. These include *Enterococcus faecalis*, *S. aureus*, *Lactobacillus acidophilus*, *Gemella morbillorum*, *E. coli*, *Klebsiella*, *Acinetobacter*, *Streptococcus sanguis*, *Streptococcus bovis,*and *Candida albicans*. The majority of cases are caused by enteric organisms.[46,50,51]There tends to be a significant time lag between stent placement and an infection becoming clinically manifest—the average gap being approximately 9 months. Clinically, the majority of patients will have conjugated hyperbilirubinemia and tender hepatomegaly in association with

a fever.[51] It has been suggested that this type of infection should be treated in a similar manner to prosthetic valve endocarditis, with sustained antibiotic therapy tailored to a cultured organism.[46]

Studies evaluating antibiotic prophylaxis for TIPS procedures have yielded conflicting results. Despite this, their use is widespread given the presence of multiple medical comorbidities and poor tolerance for infective complications in this patient population. Third-generation cephalosporins, such as 1 g ceftriaxone intravenously once daily for 48 hours, are commonly used although there is no first-choice agent recommended by SIR.[29,33] Ampicillin/sulbactam is an alternative choice, and a vancomycin or clindamycin combination with an aminoglycoside can be used as a prophylaxis regimen in penicillin-allergic patients.[33]

Inferior Vena Cava Filter Placement and Removal

IVC filters are placed to prevent potentially fatal pulmonary embolic events by trapping embolized thrombus originating from the lower extremity or pelvic veins, usually in patients with a predisposition to or established deep venous thrombosis in which anticoagulation is contraindicated or ineffective. Most filters are constructed from nitinol and are available in various shapes and configurations. The most common design is that of a funnel with struts at its base anchoring the filter to the IVC wall and the apex pointed cranially toward the heart. IVC filters can be divided into retrievable or permanent filters. Retrievable filters can be placed and left in situ for weeks to months prior to being retrieved or left in permanently.

Similar to the insertion of central venous catheters, IVC filters can be placed via a jugular or femoral approach under a combination of ultrasound and fluoroscopic guidance and is classified as a clean procedure. Infection following placement of an IVC filter is exceptionally rare but isolated cases have been reported, usually in the coexistence of infected central venous access catheters.[33,52] When performed through "fresh" venous access, routine antibiotic prophylaxis for filter placement and removal is not recommended.[31]

NONVASCULAR INTERVENTIONAL RADIOLOGY

Ultrasound-guided Procedures

In many clinical scenarios radiologically guided biopsy techniques have removed the need for open surgery to secure pathological specimens. Ultrasound is probably the modality most frequently used as a guiding tool. In addition, ultrasound is commonly used in the early stages of many other interventional techniques, such gaining vascular access for central venous catheter placement or percutaneously accessing an abscess cavity prior to drainage.

It is well recognized that ultrasound probes play a significant role in transmission of infection,[53,54] and therefore pose an infective risk in the intervention room. It was previously demonstrated by Spencer and Spencer in their seminal study that up to two-thirds of swabs taken from an ultrasound probe may ultimately culture bacteria.[55]

Aside from the preceding precautions, additional measures are taken to ensure sterility in interventional procedures. Ultrasound requires the presence of coupling gel to transmit the ultrasound waves from the probe to the patient's tissue. In routine practice, the gel used is nonsterile. However, in the intervention room, sterile gel is used in the form of single-use sachets. Additionally, a sterile plastic cover is used to

cover the ultrasound probe and the control panel of the ultrasound machine. It is common practice to routinely scan the area to be biopsied prior to adopting full sterile precautions. This is both to ensure that the radiological characteristics of the lesion render it amenable to biopsy and to plan a precise biopsy site. Although ultrasound gel is known to allow the growth of bacteria,[56] it has been shown that its use prebiopsy does not result in increased rates of biopsy site asepsis. In terms of the location of the biopsy, there is increased postbiopsy bacterial growth from covered sites such as the breast and abdomen when compared with exposed areas such as the neck. Similarly increased levels of bacterial growth can be demonstrated in areas with increased numbers of hair and skin folds such as the axilla. Therefore, particular care to aseptic technique is required in these locations.[56]

Drainage Procedures

Percutaneous Nephrostomy

The technique of ultrasound-guided percutaneous nephrostomy involves accessing the renal collecting system to allow percutaneous drainage of an obstructed or infected renal collecting system. It may also be performed as the first step in a percutaneous nephrolithotomy procedure to treat renal calculi. The patient is placed in the prone position. Ultrasound is used to guide access to the renal collecting system. The lower pole calyx is preferentially accessed to reduce complications such as pneumothorax. Generally, a 21G needle is used to gain initial access. The remainder of the procedure is performed under fluoroscopic guidance. Once in place, a guidewire is passed through the needle into the renal pelvis and a triaxial catheter is then passed over the wire to secure access. The drain to be inserted is usually 8 to 10 French in size and is inserted over the wire into the renal pelvis.

Infectious sequelae, however, are relatively frequent when compared with other interventional techniques. When they occur, they range from transient bacteruria to acute onset of frank urosepsis. Sepsis is a particular risk when dealing with pyonephrosis rather than a bland obstruction. The reported rate of urinary tract infection (UTI) as a result of percutaneous nephrostomy can be as high as 14 percent. This proportion increases in those patients with a longer term drain in situ, in whom the incidence of UTI can be as high as 27 percent.[57] The general incidence of septicemia in the literature is approximately 1 to 4 percent; however, some groups have reported incidences of as high as 21 percent, although the definition of true sepsis appears to vary in the literature.[58,59]

In patients with an established pyonephrosis, the risk of urosepsis is significantly higher than patients without it. The mechanical agitation involved in obtaining access and passing a catheter into the renal pelvis can force infected urine into the circulation, leading to bacteremia and precipitating sepsis. In such cases, a short procedure time is preferable with as little mechanical disruption of the collecting system as possible. This includes foregoing the usual nephrostogram (contrast study of the renal collecting system) unless absolutely indicated.[60] Probably the best way of reducing the risk of sepsis in these scenarios is to decompress the pelvis as soon as the drainage catheter is placed. In addition, the placement of urinary stents or other foreign bodies should be delayed in patients with known infection.[60] The most commonly implicated organisms are *E. coli*, *Proteus*spp., *Klebsiella*spp., and *Enterococcus*spp.[60]

Patients can be stratified into high and low infective risk prior to nephrostomy insertion. Those with positive urinalysis or culture, struvite stones, diabetes, or a urostomy should be classified as high risk. High-risk patients have a significantly higher incidence of sepsis than their low-risk counterparts. Both

low- and high-risk patients benefit from the use of prophylactic antibiotic in the periprocedure period and prophylaxis is recommended by the SIR, although antibiotic protocol varies from institution to institution. Routine nephrostomy tube change in uninfected patients does not require antibiotic prophylaxis.[33] Gram-negative coverage is important and, in frankly septic collecting systems, broader spectrum coverage is desirable. Common choices include a cephalosporin, ampicillin/sulbactam, or ampicillin/gentamicin combinations.[33,60]

Percutaneous Biliary Drainage

Another commonly performed interventional technique, percutaneous biliary drainage is most frequently indicated in the treatment of malignant, and occasionally benign, biliary obstruction. In addition to relieving obstruction, the procedure offers diagnostic benefits, providing radiological delineation of an obstructed system and in some cases cytological evidence of underlying malignancy. With the patient in the supine position a 21G needle is inserted in the midaxillary line. It is then passed caudally toward the xiphisternum through the liver parenchyma under fluoroscopic guidance. The needle is advanced in increments, with iodinated contrast being instilled at intervals to confirm needle position within the biliary system. When the biliary tree has been entered, wire access is obtained via the 21G needle. Once in place, a similar technique to percutaneous nephrostomy insertion is used to place the biliary drain. Once accessed, the drainage catheter can be used as the starting point to dilate biliary strictures, insert biliary stents, and remove stones.

Infectious complications are perhaps the most common of any interventional technique. Using the classification system for predicting the sterility of interventional procedures, bile duct drainages will be classified as dirty in up to 30 percent of malignant obstructions and 60 percent of benign obstructions. In these instances the risk of infectious complications can be as high as 40 percent. At best, biliary drainage can be classified as a clean/contaminated procedure.[33] In addition, many patients attending for this procedure have advanced malignancy and may have established sepsis. The complication rate, including infection, is lower in patients with benign disease. The proliferation of interventional radiology means that the importance of percutaneous biliary drainage as a cause of biliary infection has substantially increased. Some centers have reported that radiological intervention has replaced choledocholithiasis as the most common cause of severe cholangitis.[61]

As with percutaneous nephrostomy, the precipitation of sepsis is felt to be caused by mechanical agitation of an infected biliary system causing bacteremia. In addition, the passage of a needle through the liver has the potential to provide temporary communication between the biliary system and the surrounding vasculature, allowing passage of bacteria from infected bile into the blood. Risk factors for developing sepsis include bilioenteric anastomosis and previous instrumentation.[29] Risk factors for contamination of the bile prior to intervention include older age, diabetes, acute cholecystitis, and previous biliary surgery. Clearly many patients presenting for percutaneous biliary intervention will fall into at least one of these demographic groups.

In cases of fatal biliary sepsis of any kind, the most common causative organisms are *E. coli* and *Clostridium*, which account for 75 percent of cases.[29] Other organisms commonly isolated from the biliary tree include *Klebsiella*, *Enterobacter cloacae*, *Streptococcus viridans*, *Bacteroides*, and various yeasts.[38]

Because of the high rate of infectious complications, the routine use of prophylactic antibiotics is advocated. There is little agreement in the literature regarding the most appropriate coverage for biliary procedures. The high rate of biliary excretion of third-generation cephalosporins means they are ideal

for use as antibiotic prophylaxis in biliary cases and 1 g ceftriaxone intravenously is a common choice. Alternatively 1.5 to 3 g ampicillin/sulbactam intravenously can be used, this having a greater activity against *Enterococcus* spp.[33,38] In the absence of sepsis, antibiotic cover should continue until the system is fully drained. Vancomycin or clindamycin in combination with an aminoglycoside can be used in penicillin-allergic patients.[33]

Vertebroplasty

Pioneered in the mid-1980s, vertebroplasty involves the instillation of polymethylmethacrylate (PMMA) cement into the vertebral body via a radiologically sited trocar. It is indicated in the treatment of painful osteoporotic or malignant compression fractures unresponsive to conservative management.

With the patient lying prone, a 10G to 15G needle (depending on the vertebral level to be treated) is inserted through the midpoint of the pedicle of the vertebra to be treated. Again, there is variation among centers about whether a unipedicular or bipedicular technique is used, but no significant difference in outcome has been demonstrated between the two.[62] Alternatively, a posterolateral approach can be used. If cervical vertebrae are being treated, anterolateral access is obtained. Fluoroscopic guidance is used, occasionally with computed tomography as an adjunct. Once the needle is in situ, PMMA cement is instilled into the vertebral body. High volume injection is classified as >3 mL with low volume being <3 mL. Multiple levels can be treated in one session.

As with most other interventional procedures, the infective complications from vertebroplasty are rare. However, when they do occur, they can be devastating, as clearance of any infection without vertebrectomy is unlikely.[63] The etiology of infection in this setting is not clear. Although it may arise from direct seeding from the skin, the survival of any organism through the procedure would be surprising, given that the instillation of cement is followed by intense heating as the cement solidifies. Nonetheless, this seems to be the primary source of many of the reported cases of infections, particularly given the type bacteria involved in many cases. In this light, the importance of strict asepsis of the operating environment is again emphasized. Some operators perform vertebroplasties in an operating room rather than an interventional suite because of the alleged improved sterility.[64] Some cases have been linked to recent or concurrent systemic infection, including cholecystitis, meningitis, and UTI.[65] In this regard, the importance of ensuring the patient is free from infection prior to vertebroplasty is emphasized. In particular, some commentators have discussed the importance of recognizing occult UTI in the elderly. The prevalence of bacteriuria in the elderly population can be as high as 19 percent. It has been suggested that patients attending for vertebroplasty should be screened for symptoms of UTI to avoid occult systemic infection, which could complicate the postoperative course.[63] Several of the cases reported have occurred in immunosuppressed patients. The risk of underlying immunosuppression is high, given the association between high-dose steroid treatment and the propensity to osteoporosis and frequent treatment malignant compression fractures.

The presentation of infection in the postvertebroplasty patient is variable. In some reported cases clinical presentation is subacute, within the first 2 weeks post procedure, whereas in other cases infection has been diagnosed up to 8 months after the procedure. Clinically, infections reported tend to be cases of vertebral osteomyelitis, although spondylitis and spondylodiscitis have also been described. Abscess formation is also a possibility.[64,66] The species of organism is variable; *Staphylococcus epidermidis*, *Enterobacter* spp., *S. aureus*, *Serratia marcescens*, *Streptococcus agalactiae*, *Stenotrophomonas maltophilia*, and *Burkholderia cepacia* have all been implicated.

Lengthy antimicrobial therapy is generally needed. Up to 6 months of medical therapy has been described. Because of the poor vascular supply of the affected area, surgical intervention is often ultimately required for definitive treatment. Most authors advocate the use of prophylactic antibiotic treatment with 1 g cefazolin in the preprocedure period. The use of antibiotic treated cement has been described, but its use is not routine.[61] The use of a longer course of antibiotic treatment in the periprocedure period has been suggested for patients who have a concomitant or recent systemic infection.[64,67]

Conclusions

The specialty of interventional radiology is a rapidly growing field that will come to play a role in the treatment of an ever-increasing range of diseases. As the specialty develops, the universal adoption of comprehensive infection prevention practices will become vital. Serious infection is rare following interventional procedures; however, the results of such infections can be devastating. Following strict procedures regarding sterile technique reduces the risk of infection. This pertains in particular to hand hygiene, patient draping, skin preparation, and good operator technique. Following Standard Precautions in the intervention room can minimize transmission of bloodborne infection. The use of prophylactic antibiotics reduces the risk of infection in a wide variety of procedures, but their use must be tailored to the likely causative organisms. There are specific complications associated with each interventional technique, and some procedures place patients at higher risk than others. However, constant vigilance is required during and after any procedure if infection is to be kept to a minimum in this field.

Future Trends

With the explosive growth in types and quantities of procedures performed in the interventional radiology setting, it can be anticipated that the need to qualify and quantify patient outcomes through surveillance will be of interest. It can be anticipated that with changing reimbursements for inpatient settings the number and types of procedures performed in this setting will likely increase.

International Perspective

The techniques involved in the field of interventional radiology were pioneered in the United States and Germany, but were gradually adopted throughout the world. The field of interventional radiology is now essentially universal in first-world healthcare systems. In a similar manner, the challenges faced regarding infection prevention in the interventional suite are ubiquitous and rigid standards are being adopted globally to minimize infectious complications.

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Long-Term Care

Author(s): Mandy Bodily-Bartrum, RN, MPH, CIC
Director of Quality and Risk Management

Vibra Hospital & Vista View Care Center
Thornton, CO

Janet Franck, RN, MBA, CIC
Infection Preventionist/Consultant

Chicago, IL

Linda Spaulding, RN, BC, CIC
InCo and Associates International, Inc.

Lakewood Ranch, FL

Jolynn Zeller, RN, BSN, CIC
Coordinator, Infection Prevention

Avera St. Luke's
Plymouth, MN

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Abstract

Long-term care facilities function in a unique setting along the postacute continuum of care. Federal, state, and local government authorities have regulatory standards for infection prevention in this setting. Long-term care facility residents are at high risk for developing infections. Infections in this setting account for a large number of acute hospital transfers, mortality, and increased costs. The infection preventionist in the long-term care facility should be knowledgeable about regulatory compliance issues and have a basic understanding of surveillance, evidence-based practices, and interventions to reduce risk. Infection prevention activities across all departments are important to ensure that safe and quality care is given to residents within the long-term care facility setting.

Key Concepts

- The long-term care facility provides a home for elderly, physically disabled, and cognitively impaired residents, presenting unique challenges for the infection prevention and control program.
- The medical complexity of residents and the increased presence of invasive devices (intravascular catheters, ventilators, indwelling Foley catheters, etc.) in the long-term care environment have led to the increased need for infection surveillance in these settings.
- Long-term care facilities must balance resident psychosocial needs with infection prevention guidelines to provide a safe environment while maintaining quality of life.
- State and federal regulatory requirements play an important role in infection prevention and control programs in the long-term care environment.

Background

Long-term care (LTC) is an umbrella term that encompasses several different types of facilities to provide care for individuals who cannot achieve independent self-care in the community; they are generally referred to as long-term care facilities (LTCFs).[1] The LTC environment spans the spectrum of care from providing short-term, episodic skilled nursing and residential support to chronic care management. It is a setting in which medical, physical, and psychosocial services are provided to support the needs of persons living with chronic health problems. These health problems may interfere with residents' ability to perform activities of daily living (ADLs).

Currently, more than 310 million adults in the United States are over the age of 60, and that number is expected to increase by nearly 25 percent by 2030.[2] It is expected that nearly 70 percent of adults aged 65 or older will utilize LTC in some capacity during their lifetime[3]; currently more than 1.5 million people reside in LTCFs.[4] Acuity of populations served within the LTC environment continues to increase, which in turn increases the risk for healthcare-associated infections (HAIs) within this specialized setting.[4]

The Association for Professionals in Infection Control and Epidemiology, Inc. (APIC), proactively created a LTC member section—a group for infection preventionists (IPs) engaged in this level of care to meet the challenges unique to this setting.[5] This chapter serves as a guide for planning and implementing infection prevention activities in LTCFs.

Basic Principles

Most commonly, residents who occupy LTCFs are over 65 years of age, with the mean age of 80.[4] Therefore, it is imperative that the IP is aware of the issues regarding aging. The aging population faces challenges to combating infection as their immunological systems become compromised as a result of changes related to aging, malnutrition, comorbidities, and medications that may alter their immune status.[6] The presence of compromised host defenses in elderly persons (e.g., decreased or absent cough reflexes; thinning skin barriers, reduced production of tears, blunted fever response, etc.) also predisposes them to infection problems. Inflammatory responses, particularly febrile responses, are often diminished among the elderly population, presenting a challenge for identifying signs and symptoms of

infections.[7] Furthermore, elderly persons often experience altered responses to pharmacotherapy, presenting as decreased therapeutic response or the potential for increased occurrence of toxicity from therapeutic medications. (See **40. Geriatrics** for more detailed information about this population.)

Prevention of HAIs should be of high importance to the IP in the LTCF. Residents in LTCFs may be chronically dependent on ventilators, have indwelling urinary catheters, or have long-term indwelling central venous catheters. Longevity of stay within LTCF, for many residents, places them at greater risk for HAIs. In addition, many primary healthcare personnel (HCP) in LTCFs are nursing assistants or nonprofessionals who may not have a complete understanding of infection prevention, healthcare delivery, and the special needs of elderly or infirm persons. Detection of infection symptoms is often also more difficult because of varying levels of resident cognition and altered mental status, which may or may not be understood or interpreted by the HCP. Due to all of these factors, it is imperative that sound infection prevention practices are in place to ensure that a high quality of care is delivered.

A key difference and challenge between the LTCF and acute care setting is the concept of residence. Being considered a residence, the LTCF offers socialization through common activities. These activities provide several important positive aspects in the life and well-being of the resident but are also fraught with risks for infection through potential exposure to communicable diseases with close, frequent contact with other residents, HCP, visitors, or volunteers.[4] LTCFs generally have common air circulation, which may contribute to infection transmission of pathogens that are airborne. Additionally, the sharing of many types of resident care equipment may contribute to microbial transmission by contact if proper cleaning and disinfection between residents is not ensured. An emerging, significant risk factor in LTCFs involves enhanced infection risks for colonization or infection with multidrug-resistant organisms (MDROs).

Rules and Regulations

LTCFs must comply with federal and state regulations and may also voluntarily participate with other compliance agencies such as The Joint Commission (TJC). The Nursing Home Reform Act as part of the Omnibus Budget Reconciliation Act (OBRA) of 1987 mandated that LTCFs have an infection prevention and control program within the facility.[8] For LTCFs that provide services to residents on Medicare and/or Medicaid, the Centers for Medicare & Medicaid Services (CMS) also has regulations to ensure that an infection prevention and control program is place.[9] CMS mandates that this program includes items such as infection surveillance, implementing practices to prevent spread of infection, use of proper isolation measures, appropriate employee health policies, hand hygiene practices, and proper handling, processing, and storing of linens.[10,11]

The Occupational Safety and Health Administration (OSHA) is part of the U.S. Department of Labor. OSHA regulations are designed specifically to protect employees. Compliance with federal and/or state OSHA standards is required.[12,13] LTCFs must meet minimum federal requirements for construction and design projects.[14] In addition, in 2005 CMS published a final rule mandating that LTCFs offer annual influenza immunization and lifelong pneumonia immunizations to their residents.[15] LTCFs must also provide education to the resident and/or legal representative regarding the benefits and side effects of these immunizations. See Table 61-1 for a list of agencies and organizations that have resources for LTC program compliance.

Tuberculosis Guidelines

Tuberculosis (TB) may be a challenge in the LTCF. There have been case reports of high TB transmission rates in LTCFs.[16] Signs of TB are often nonspecific and can be difficult to diagnose without the use of chest x-ray or other diagnostic aids. It is recommended that facilities have regular TB screening programs for residents. Facilities should determine whether they have the ability to isolate a resident with TB (negative pressure rooms, fit-testing program for employees, and available N95 respirators). If a facility does not have airborne isolation capability, a pre-arranged plan should be put into place to transfer residents who with suspected TB.

TB exposure control programs are mandated by OSHA as part of the Respiratory Protection Standard. The Centers for Disease Control and Prevention (CDC) published their most recently updated TB guidelines in 2005.[17] These guidelines identify high-risk groups, which include LTCFs, and provide recommendations for screening residents on admission and for conducting a TB program. Most LTCFs do not have private rooms with potential for negative-pressure airflow and therefore cannot properly care for a resident with suspected or identified TB. These residents must be sent to facilities that have the capability to implement proper Airborne Precautions. If a case is detected, all residents and employees should be evaluated and TB skin tested (TST) according to guidelines. Refer to state and federal guidelines for guidance on conducting a risk assessment (see **95. Tuberculosis and Other Mycobacteria**).

Education of Employees

All employees in LTCFs must be educated about infection prevention. The IP should provide orientation to all new employees and additional training for nursing personnel on a continual basis and as concerns arise.[18] Education should focus on general and facility-specific issues related to elderly persons and others being served in the LTC setting. The minimum orientation program for all new employees should include the following:

- Reinforcement of physiological and other infection risks in elderly or other LTC residents
- Education about the importance of appropriate hand washing and hand hygiene
- Information about personal hygiene
- Training related to the cycle of infection and the prevention of transmission of infection
- Outbreak investigation
- Explanation of resistant organisms and methods to prevent transmission, including isolation precautions/techniques, detailed at a level understandable to the orientees
- Training in Standard and Transmission-based Precautions
- Techniques for resident assessment related to infection identification for all direct care providers, including nurses and nursing assistants
- Employee health, illness, immunizations, TST, and management of exposures
- The facility's bloodborne pathogens plan
- The facility's TB exposure control program
- Facility policies for sanitation and appropriate linen and trash handling
- Special emphasis on care of the resident's environment

Table 61-1 . Compliance Resources for the IP in the Long-Term Care Setting

Agency	Source

State regulations/ standards	*Access to state official websites:* **http://www.cdc.gov/mmwr/international/relres.html**
Centers for Medicare & Medicaid Services	*Omnibus Budget Reconciliation Act (OBRA):* **http://www.cms.hhs.gov/**
Occupational Safety and Health Administration	*OSHA TB:* **http://www.osha.gov/** *OSHA Bloodborne Pathogen and Needlestick injury:* **http://www.osha.gov/SLTC/bloodbornepathogens/index.html**
U.S. Food and Drug Administration	**http://www.fda.gov/** *Medical Device Reporting Patient Safety News:* **http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/psn/index.cfm**
Environmental Protection Agency	**http://www.epa.gov/** *Medical waste:* **http://www.epa.gov/osw/nonhaz/industrial/medical/mwfaqs.htm** Medical waste regulations can also be accessed by state.
Centers for Disease Control and Prevention	**http://www.cdc.gov/**
American Health Care Association/ National Center for Assisted Living	**http://www.ahcancal.org/Pages/Default.aspx** Provides updates on laws, regulations, and standards
Long Term Care Resources	**http://www.longtermcare.gov** Outlines long-term care resources relating to cost and nursing home compare
American Medical Directors Association	**http://www.amda.com/**
American Association for Long Term Care Nurses	**http://ltcnursing.org/**
Annals of Long Term Care	**http://www.annalsoflongtermcare.com**
Advancing Excellence Campaign	**www.nhqualitycampaign.org**
Assisted Living Facilities	**www.assistedlivingfacilities.org/**
National Citizens Coalition for Nursing Home Reform	**www.nccnhr.org**
National Gerontological Nursing Association	**www.ngna.org**
National Resource Center on Native American Aging	**www.med.und.nodak.edu/depts/rural/nrcnaa/**
National Transitions of Care Coalition (NTOCC)	**www.ntocc.org**

Infection Prevention–Related Education for Nursing Assistants

Because nursing assistants often provide more than 80 percent of direct care to residents, facilities may consider enhancing the important role of nursing assistants—that of identifying and reporting possible "infection clues." Because nursing assistants often first observe clusters of infections, they are often the best first line of defense against preventing an outbreak. Furthermore, this early identification and treatment of resident illness can prevent having to transfer the resident to an acute care facility for treatment of a more complicated infection.

The IP can help the nursing assistant develop the ability to detect important signs of infection problems in residents. Educational efforts must creatively explore methods to do the following:

- Teach how to incorporate personal hygiene practices including hand hygiene and respiratory etiquette into the residents' care.
- Teach how to identify, document, and report signs and symptoms of infection.
- Provide commonly understood language (often "lay language") to describe these signs and symptoms to nursing.
- Instruct nursing assistants how to communicate data that have been observed and to whom to report the information.
- Ensure that data reported will be investigated.

Risk Assessment

An annual risk assessment provides the IP with quantifiable information that helps define surveillance objectives and creates the foundation for developing specific strategies to reduce infection transmission. The risk assessment helps the IP identify surveillance needs according to activities that are high risk, high volume, or problem-prone. Those that identify trends or problems or needed improvements to enhance resident safety, improve quality of care, and improve resident satisfaction help the IP prioritize surveillance and programming efforts. The risk assessment may be based on resident history and physical findings; identified MDROs (colonization or infection) within the facility or community; presence of invasive devices and procedures; prevalence of infections within units and the facility; and community, state, and national levels of infections.[17] Although the routine risk assessment typically includes items listed above, facility issues or characteristics impacting the LTC continuum of care may also be integrated into the risk assessment and surveillance objectives to allow measuring of outcomes and improved quality of care.

Special Considerations for Infections in Long-Term Care

Urinary Tract Infections

Urinary tract infections (UTIs) remain a common problem within the LTCF setting.[19] Residents in the LTCF setting often have bacteriuria, though this is not commonly associated with adverse outcomes in these residents (i.e., asymptomatic bacteriuria).[19] Traditional symptoms of a UTI include fever, flank pain, dysuria, urnation urgency, and frequency.[4,19] UTIs can also be associated with altered mental status, declining ADL scores, and new-onset incontinence in residents.[19]

In 2008, it is was estimated that 15 percent of residents within a LTCF had a urinary catheter.[20] Since that time, the inappropriate use of urinary catheters has been discouraged primarily because residents

with an indwelling urinary catheter are at greater risk of UTIs and are also at higher risk for a secondary bacteremia, often called "urosepsis."[21,22] Bacteria cultured from these patients is often found to be resistant to many common oral antibiotics that have typically been utilized in the community setting.[23] Because LTC residents with indwelling catheters are often colonized with infectious pathogens, it is recommended that residents with asymptomatic bacteriuria not be routinely screened and treated (see **33. Urinary Tract Infection**).

Alternatives to indwelling urinary catheters often found within the LTCF environment may include intermittent catheterization, suprapubic catheters, and external catheters. Preferred method for catheterization types from least risk of UTI to greatest risk of UTI are (1) external urinary devices, (2) intermittent catheterization, (3) suprapubic catheterization, and (4) indwelling urinary catheterization. To promote uninterrupted sleep, external urinary devices may be used at nighttime as an alternative to indwelling urinary catheterization with male residents who are incontinent or have urinary urgency; these devices may be used in conjunction with a toileting schedule during the daytime hours to promote independence.

Leg bags are commonly used within the LTCF to improve mobility in the client with a urinary catheter. Leg bags may pose risk for infection due to reflux of urine as well as frequent changing between urinary bags that open the urinary collection system. Therefore, it is important that any changes to the urinary collection bag be done using aseptic technique, cleaning the connecting ports with alcohol, and cleaning the leg bag between uses.[24]

Respiratory Infections

Respiratory infections may often cause significant illness for elderly persons in the LTCF setting.[4]

Common respiratory infections in this population include upper respiratory infections, bronchitis, pneumonia, and TB. Viruses including respiratory syncytial virus, influenza, and adenoviruses, and bacteria including *Haemophilus influenzae*, staphylococci, and streptococci may cause respiratory tract infections in elderly persons in LTC due to the decline of immunologic memory as part of the aging process.

Pneumonia causes a high rate of infection every year and is a leading cause of death. Residents in LTCFs are often predisposed to pneumonia because of the use of feeding tubes, issues with swallowing and aspiration, inability to clear their airways, decreased functional status, and insufficient oral care.[25] A number of bacteria and viruses can cause pneumonia. Pneumonia may present atypically amongst the elderly population, with fever being the most common symptom, followed by new or increased cough and altered mental status.[25] Because of the risk of pneumonia caused by *Streptococcus pneumoniae* in elderly persons, Advisory Committee on Immunization Practices (ACIP) recommends that the pneumococcal vaccine (PPSV23) be offered to all unvaccinated residents who are age 65 and older, including persons who have not received vaccine within 5 years who were under 65 years of age at the time of vaccination. Multiple revaccinations are not recommended by ACIP because of lack of evidence of clinical benefit and safety[26] (see **36. Pneumonia**).

Elderly persons living in group settings, including LTCFs, are also susceptible to circulating influenza viruses. Factors placing residents of LTCFs at high risk for influenza infection include their proximity to other residents, the frequency and closeness of HCP contact, and potential for exposures to visitors and family from the community. In addition, influenza can be spread 1 to 2 days prior to symptoms being present, creating a challenge for containing transmission in these settings. Furthermore, influenza may

present with atypical signs of infection among LTCF residents, resulting in a delay of diagnosis and implementation of infection prevention strategies.[4]

Influenza outbreaks have been described in LTCFs related to poor vaccination rates among HCP, as well as residents. Influenza outbreaks in LTCFs may have severe and even deadly consequences for residents. Because influenza is easily transmitted, it is important that influenza vaccination is offered to all residents during influenza season, which provides both individual protection and "herd immunity" (i.e., group protection) in the LTCF. Residents with suspected cases of influenza should be separated from other residents to reduce the risk of transmission. Laboratory confirmation of influenza is important to ensure implementation of effective infection prevention and treatment strategies, including use of antiviral medications effective against influenza (see **82. Influenza**).

Skin and Soft Tissue Infections

Skin and soft tissue infection may include anything from pressure ulcers to cellulitis to scabies. LTCFs often have a high incidence of pressure ulcers among their residents. Pressure ulcers occur in up to 20 percent of residents of LTCFs and are associated with high mortality rates.[4,27]Osteomyelitis and secondary bacteremia may result from infected deep soft tissue infections. Residents within the LTCF setting often have increased risk for developing pressure ulcers and pressure ulcer infections. Factors for the development of pressure ulcers include immobility, incontinence, malnutrition, moisture, and long-term steroid treatment. Several prevention and treatment options are available for pressure ulcers, which may help reduce the incidence or severity of pressure ulcer infections. In addition, it is important to note that a positive culture from a pressure ulcer without signs or symptoms of infection may not be indicative of a true infection, but rather of colonization or contamination, which in most cases does not need to be treated with antibiotic therapy[4](see **92. Skin and Soft Tissue Infections**).

Gastroenteritis Illnesses (Nausea, Vomiting, and Diarrhea)

Acute gastroenteritis is significant in elderly persons because it can lead to more serious illness and complications, including dehydration, debilitation, hospitalization, and death. Elderly persons in LTCFs are at an increased risk of contracting and transmitting gastroenteritis because of the use of shared bathrooms, common dining and rehabilitation facilities, and increased close proximity to others in general. Other risks for transmission of gastroenteritis are underlying comorbidities including dementia, cognitive impairment, and decreased gastric acid.[4]

Outbreaks in LTCFs have been caused by rotavirus, enterovirus, norovirus, *Clostridium difficile*, *Bacillus cereus*, *Escherichia coli*, *Campylobacter,Clostridium perfringnes*, *Salmonella,*and *Giardia lamblia*.[28,29]

Proper food preparation and storage is important to decrease the risk of foodborne outbreaks.

Contact Precautions should be implemented immediately to prevent cross-transmission when a resident develops signs and symptoms of gastroenteritis. The resident should be restricted to an assigned bedroom and kept from participating in group activities until at least 48 hours after the last episode of diarrhea or vomiting. If two or more residents develop similar signs and symptoms of gastroenteritis, prompt investigation should be initiated using basic principles of an outbreak investigation. At many LTCFs, identification of pathogens may be delayed due to lack of access to laboratory diagnostic testing and to complexity of laboratory tests for some pathogens such as norovirus.

The following control measures are recommended in a gastroenteritis outbreak in an LTCF even when the etiology has not been confirmed:

- Hand washing is preferred over the use of hand sanitizers during an outbreak because it is felt the organism is mechanically removed from the hands during hand washing and some pathogens are not killed by alcohol-based waterless hand sanitizers.
- Residents who present with symptoms of gastroenteritis should be placed on Contact Precautions until 48 hours after symptoms resolve.
- HCP who clean and disinfect heavily contaminated areas or who are cleaning vomitus are recommended to wear a barrier mask with shield during cleaning to reduce risk of transmission.
- Cleaning and disinfection practices should be evaluated to ensure they are appropriate. It is recommended to use an Environmental Protection Agency (EPA)-approved agent effective against the suspected pathogen.
- Residents should be cohorted by symptomology. In addition, to prevent risk of transmission to other residents and HCP, staff should be designated to care for the same cohort during their shift and not rotated to assignments on other units.
- Admissions to the facility may be postponed due to the outbreak. Your local health department may have recommendations for whether this is appropriate.
- Signage to alert visitors of the outbreak should be posted.
- If visitors are restricted, provide signage that directs visitors to the appropriate source for information about restricted visitation. Ensure that family and significant others are notified of the threat of communicable disease. Avoid using the word "outbreak" on signage so as not to panic the public (including the media).
- Cancellation of group activities and trips outside of the LTCF should be considered until 48 hours after symptoms of the outbreak have ended.
- Hand hygiene and Transmission-based Precaution compliance should be reinforced with staff and residents.

Additional measures may be put in place by the facility, based on the environment and length of transmission. Some facilities choose to limit activities and close off dining areas for the duration of an outbreak to limit the spread of the illness[30](see **12. Outbreak Investigations**).

Norovirus is a common cause of gastroenteritis in the LTCF setting, causing outbreaks primarily during the winter season. Symptoms of norovirus may include vomiting, diarrhea, nausea, abdominal pain, headache, muscle aches, and fever. Norovirus spreads quickly in LTCF and other group settings because the incubation period is very short, the pathogen is very infectious, and the person is infectious prior to onset of symptoms.

During an outbreak investigation of acute-onset gastroenteritis, HCP may be instructed to report these illnesses to employee health. Staff who are ill with gastroenteritis-like illnesses should be instructed to stay home until 48 hours after symptoms resolve.[4]

For more information about norovirus, see **79. C: Diarrheal Diseases: Parasitic**.

Clostridium difficile-Associated Diarrhea

C. difficile is an anaerobic, Gram-positive, spore-forming bacillus. *C. difficile* is transmitted by direct contact by the fecal-oral route. Once the organism is orally ingested, the spores pass through the stomach and go into a vegetative state (the vegetative state is the growing, reproducing form of the bacteria) in the small intestine. When the normal flora of the colon is altered by antimicrobial use, it

provides the right environment for *C. difficile*to grow and multiply. *C. difficile*produces two exotoxins, toxin A and toxin B, which cause damage to the lining of the colon.[31]This may cause illnesses such pseudomembranous colitis or toxic megacolon.

Infection prevention precautions that should be taken to prevent transmission of *C. difficile*infection (CDI) or *C. difficile*-associated diarrhea (CDAD) include:

- Because *C. difficile*changes from the vegetative to the spore state when it contaminates the environment, surviving for long periods of time, dedicated equipment, meticulous environmental cleaning, and hand washing are essential to prevent transmission.
- Frequent cleaning of high-touch surfaces is recommended.[18,31,32]Disinfection with 1:10 bleach is recommended in the event of CDI outbreaks. Newer EPA-registered sporicidal agents consisting of hydrogen peroxide may also be used as an alternative to bleach. Use of a commercially prepared nonfragrant bleach product may be preferred due to the potent aroma of 1:10 bleach mixed at the facility.
- A resident diagnosed with CDI should be placed on Contact Precautions. Separate bathroom facilities should be provided; if this cannot be done, the resident should have a dedicated commode.
- HCP should always wear gloves when caring for the resident and wash hands vigorously with soap and water after removing the gloves. The act of vigorous hand washing dilutes and removes spores from the hands. There is conflicting information about the use of alcohol-based hand gels and hand washing. Many antimicrobials are not any more effective against spores than regular soap and water.[31]HCP should help or remind the resident to practice hand washing.
- Residents can be removed from Contact Precautions 48 hours after the cessation of diarrhea or unformed stools. Laboratory tests are not required to remove the resident from Contact Precautions and are discouraged as a "test of cure."[31]
- Place residents with more than three diarrheal stools in presumptive Contact Precautions while waiting for test results to come back; residents suspected of recurrent CDI should be placed in Contact Precautions even sooner.[31]
- Maintain a line listing of all residents in the facility that have or had *CDI.*

For further information, see **72. Clostridium difficile Infection and Pseudomembranous Colitis**.

Other Infections

As the number of intravascular devices in LTCFs has increased, so too has the number of complications. CDC guidelines for prevention of intravascular catheter-related infection recommend aseptic insertion, daily inspection, and quality control of intravenous fluids and administration sets[33](see **34. Intravascular Device Infection**).

Conjunctivitis is a bacterial or viral infection of the conjunctiva. The most common bacterial isolate is *Staphylococcus aureus.*[34]Contaminated eye drops and hand contamination have caused conjunctivitis outbreaks in LTCFs. Standard Precautions such as using gloves for administration of eye drops and ointments, as well as hand hygiene, are recommended for HCP to reduce the risk of transmitting conjunctivitis. It is also essential that the resident with conjunctivitis practices good hand hygiene and is reminded not to touch or rub the infected eye.

Other LTCF infections include herpes zoster, herpes simplex, endocarditis, hepatitis, septic arthritis, and abdominal infections.[4]

USE OF ANTIMICROBIALS IN LONG-TERM CARE FACILITIES

Antibiotic resistance will continue to pose a significant problem for residents in LTCFs because of the overuse and misuse of antibiotics.[35] A common problem within LTCFs is the failure to distinguish infection from colonization (such as a positive swab culture of a pressure ulcer or a urine culture showing asymptomatic bacteriuria) and the inappropriate treatment of the colonization with antibiotics. Another problem is the inappropriate selection of empiric antibiotics without culture evidence of susceptibility. LTCF IPs can combat the problem of antibiotic resistance by making sure that the infection prevention and control program contains elements of prevention (such as vaccination), procedures for correct identification of organisms (including instruction on proper specimen collection), and antimicrobial stewardship (treating only symptomatic infections). The infection prevention and control program should use antibiograms to focus empirical treatment until culture results are known. Policies for initiating Transmission-based Precautions to prevent transmission should be in place before the outbreak.[35]

SURVEILLANCE

Hospitals that participate in Medicare/Medicaid are required to use the National Healthcare Safety Network (NHSN) criteria for surveillance definitions. However, NHSN definitions do not address the unique issues of the LTCF and therefore may not always be appropriate for meaningful surveillance in the LTCF. In 2012, the Society for Healthcare Epidemiology of America (SHEA) and CDC released updated surveillance definitions for LTCFs (often referred to as the McGeer criteria). These definitions are widely used in LTCFs because they address common LTCF issues such as limited radiology and laboratory data, blunted immune response of elderly persons, and brief resident notes.[36] Some LTCFs may choose to adapt the home health care surveillance definitions, although LTCFs will be required to report NHSN conditions in future years.[37] No matter which criteria are used, it is most important that the definitions are accepted by the facility physicians and infection prevention and applied consistently to ensure standardized surveillance is done over time (see **11. Surveillance**).

INFECTION PREVENTION PRECAUTIONS IN LONG-TERM CARE

Standard Precautions include the use of hand hygiene and proper use of personal protective equipment (PPE) when completing tasks that produce potential exposure to blood and body fluids. HCP should determine the types of Standard Precautions needed during specific resident interactions. For a more extensive review of Standard and Transmission-based Precautions, see **28. Standard Precautions**and **29. Isolation Precautions (Transmission-based Precautions)**).

Transmission-based Precautions, particularly spatial distancing and limited mobility, present educational, social, and financial challenges to LTCFs. LTCF residents may pose an infection prevention risk to themselves and others because of their sometimes disoriented or confused mental status combined with their freedom of mobility throughout the facility. Utilizing Transmission-based Precautions in the LTCF is much different from the utilization of the same categories of precautions in the acute care setting and may require modifications to avoid negatively affecting the psychosocial wellbeing of the resident. For example, modification to Contact Precautions for with MDROs colonization versus infection may be indicated to ensure that residents have access to care and can leave their rooms for activities. Facilities and state guidelines may vary in the exact methods of modifying these precautions.

Multidrug-Resistant Organisms

Successful management of MDROs in LTCFs requires awareness by administration of both the financial and staffing commitments required.[1] The management of MDROs (such as methicillin-resistant *Staphylococcus aureus* [MRSA], vancomycin-resistant *Enterococcus* [VRE], extended-spectrum β-lactamase producing Enterobacteriaceae, carbapenem-resistant Enterobacteriaceae, and *C. difficile*) present many problems and concerns in LTCFs.[18,32,38] These include placement of residents, scarcity of private rooms, and multiple transfers between the LTCF and acute care. Private rooms are always preferred for residents with MDROs.

Colonization versus Infection

Both infected and colonized residents may serve as sources for the spread of MDROs in the LTCF. Colonization is the presence, growth, and multiplication of the organism without observable clinical symptoms or immune reaction.[1] "Infection" refers to the invasion of bacteria into tissue with replication of the organism. Infection is characterized by isolation of the organism accompanied by clinical signs of illness such as fever, elevated white blood cell count, purulence (pus), and clinical expression of disease such as pneumonia, bloodstream infections, UTIs, gastrointestinal infections, and skin infections.[18]

MRSA colonization may occur in the nares, axillae, chronic wounds or decubitus ulcer surfaces, perineum, around gastrostomy and tracheostomy sites, in the sputum or urine, and on healthy skin. One of the most common sites of colonization in both patients and employees is the nose (anterior nares). Infections can develop in any almost any site with an invasive device or an open wound. Although HCP may become colonized with MRSA (as they may with susceptible *S. aureus*), they rarely develop infections.

Enterococci are normally found in the bowel, the female genital tract, and the mouth. VRE may survive and multiply, resulting in a colonization of the bowel. An infection may develop if VRE contaminate sterile body fluids such as blood or a surgical site.

*C. difficile*is commonly found in the gastrointestinal tract. The organism, including drug-resistant and "epidemic strains," can asymptomatically colonize the bowel of individuals. Residents receiving antimicrobial therapy may be especially susceptible to developing CDI. Generally, there are more asymptomatic carriers than CDI patients. Although no symptoms may be evident, the colonized resident may test positive for the organism or its toxin(s). Residents with CDI may have symptoms of 3 to 20 unformed stools per day, abdominal cramping, and leukocytosis (> 10, 000 white blood cells/mm^{3}to > 40,000 white blood cells/mm^3).

Multidrug-resistant Gram-negative bacilli colonization may occur on the skin (healthy skin and wounds) and the respiratory tract of both HCP and patients. Colonization may also occur in the bowel, where these organisms may occur as normal intestinal flora. Infection may develop in residents who are colonized if they become immunocompromised and have a port of entry. As with other MDROs, infection of HCP is rare.

*Acinetobacter baumannii*colonization may occur on multiple areas of the skin, including the axillae and groin, as well as the respiratory tract. Residents may also have colonized wounds and occasionally the bowel. Colonization is particularly heavy during outbreaks.

Klebsiella pneumoniae and other Enterobacteriaceaemay colonize wounds, healthy skin, the bowel, and the respiratory tract of residents and HCP.

Transmission-Based Precautions for Residents with MDRO Colonization and Infection

Contact Precautions may be utilized for patients who have acute transmittable infection or colonization with MDROs. Staff caring for residents on Contact Precautions should wear a gown and gloves when caring for the patient.[1,18,32,38]

Transmission-based Precautions are currently recommended for the LTCF setting by Society for Healthcare Epidemiology of America/APIC Guidelines.[4] Modification of Contact Precautions is common among LTCFs to balance the psychosocial needs of residents with the need to decrease transmission of infection.[39] Gowns and gloves are used for contact with uncontrolled secretions, pressure ulcers, wounds, stool, and ostomies. Contact Precautions are recommended for residents with MDROs who are totally dependent on HCP and whose secretions cannot be contained. Single rooms are recommended for residents with MDROs, but cohorting is an acceptable alternative. If possible, first cohort patients with the same MDRO. If this is not possible, LTCF residents with MDROs can be cohorted with residents who are not immunosuppressed, not on antibiotics, and are free of open wounds, drains, and urinary catheters. LTCF Contact Precautions include wearing gown and gloves for all interactions that may involve contact with the resident and their environment.

In general, Droplet and Airborne Precautions for the LTCF are similar to those used in the acute care setting.

OUTBREAK CONTROL

Outbreak surveillance is a high priority for LTCF IPs. An outbreak should be considered when the number of cases exceeds the normal baseline. The CDC recommends defining an influenza outbreak as a single laboratory-confirmed case or a sudden increase of acute febrile respiratory illness.[40] A low outbreak threshold allows for strategy implementation before the attack rate increases. Single cases of TB, *Legionella* spp., scabies, *Salmonella* spp., or other gastrointestinal pathogens trigger outbreak investigations.

The CDC/SHEA guide to investigation of outbreaks recommends the following steps: determine if an outbreak has occurred, develop a case definition, find cases, analyze the outbreak, formulate a mode of transmission hypothesis, and designate and evaluate control measures.[41]

Influenza and norovirus outbreaks are common in LTCFs. ICPs should preemptively create plans for these outbreaks. To facilitate rapid control measures in outbreak situations, it may be helpful to create preexisting case definitions and policies and procedures and to obtain consent for influenza vaccination at time of admission (see **12. Outbreak Investigations**).

RESIDENT HEALTH AND WELLNESS

LTCF resident health and wellness programs are recommended to prevent infections.[4] Elderly populations are underserved in vaccinations for tetanus, pneumococcal disease, and influenza. Recommended immunizations for the LTCF resident include tetanus, pneumococcal disease,[38] and influenza along with TST. Standing orders for immunizations are recommended to increase vaccination rates. Other resident care practices that should be addressed are resident hand hygiene, respiratory etiquette, oral hygiene, prevention of aspiration, skin care, and prevention of UTIs.

LINEN MANAGEMENT

General principles of linen and laundry management apply, regardless of facility type or location. These general principles are included in **111. Healthcare Textile Services**. However, the process for managing a supply of clean linens and for providing residents with clean clothing provides challenges that are not experienced in acute care. These processes often involve creating linen and laundry services on-site rather than transporting linens to be processed at a professional, off-site laundry. Family and significant others may also choose to wash the resident's personal laundry. Challenges involve ensuring that laundry staff are aware of the principles for safe sorting, washing, and storing of linens and resident laundry (Healthcare Laundry Accreditation Council). For example:

- A physical barrier should exist between clean, stored linen and contaminated, soiled linen.
- To avoid recontamination of cleaned linen with contaminated lint or dust, areas for receiving dirty linen should be at negative air pressure relative to the clean areas.
- All linen storage should be locked or in an area away from confused or inquisitive residents who may enter an unlocked storage room and handle linen.
- Shelves, carts, folding tables, etc. should be cleaned at scheduled intervals.
- Transport of bulk clean linen to residents' rooms should be done in a clean, covered cart.
- Routine disinfection practices apply.
- Persons working in the laundry should wear the appropriate PPE, such as gloves and gowns, while sorting soiled linen.
- Laundry rooms should have a sharps container.
- Laundry washing and drying temperatures must adhere to state or national requirements.

In addition, differences between acute care and LTCF laundry involves issues relating to cleaning not only facility linens but also residents' clothing, recognizing the many challenges that may present because of a variety of fabrics and colors, as well as individual preferences for residents' clothing. Some general principles for resident clothing may include the following:

- All resident clothing must be marked with the resident's name to ensure that clothing is returned to the right person.
- Residents and families should be encouraged to provide clothing that is washable and able to withstand repeated washing at required laundry temperatures.
- Residents may desire to have their own blankets and throws, which should be marked with a process similar to that used to mark the residents' clothing.
- Install a sharps container in the laundry for use in the event that sharps (e.g., needles, scalpel blades, razor blades, glass ampules) accidentally end up in soiled linen.

FACILITY MANAGEMENT

The LTCF IP should partner with the environmental services department to ensure infection prevention practices are incorporated into Environmental Services policies and procedures. The IP should also partake in periodic environmental compliance rounds. During these rounds, the IP should monitor dishwasher and laundry temperatures, evaluate sterilization, observe disinfection and asepsis processes, monitor disposable equipment, and monitor compliance with infection control techniques such as hand hygiene and respiratory etiquette.

Guidelines for disinfection are applicable to the LTCF. IPs should assist in selecting proper disinfectants and infection prevention products such as urinary catheters, gloves and gowns, etc.

Waste management policies and procedures should follow EPA, OSHA, CDC, and state and local health department regulations. Waste management guidelines apply to the LTCF.[42,43,44,45] See **107. Environmental Services** and **113. Waste Management** for additional information.

OTHER PROGRAM ASPECTS

In addition to components discussed in this chapter, other aspects of the infection prevention program in a LTCF may include employee health, antibiotic stewardship, education, policy and procedure development, and emergency and disaster planning. See **26. Antimicrobials and Resistance**, **100. Occupational Health**, and **119. Emergency Management** for more detailed information.

Conclusions

LTCFs must comply with federal, state, and local legislation and standards that play a major role in defining the infection prevention and control program. IPs in the LTCF should be knowledgeable about compliance issues, have a basic understanding of surveillance, and be familiar with the infection prevention issues specific to LTCF populations, who are generally elderly, physically disabled, and/or cognitively impaired. IPs must also accommodate any infection prevention needs specific to their facilities and residents. Surveillance is increasingly critical in the LTCF environment. Infection prevention and control programs should be designed to correlate key surveillance activities with recommendations of appropriate accrediting agencies, legal requirements, and identified opportunities to improve the resident health, including activities intended to prevent illness.

Additional Resources

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ADDITIONAL GUIDELINES AND CLINICAL PRACTICE CONSENSUS GUIDELINES

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Long-Term Acute Care

Author(s): Sharron Knox, BSN, RN, CIC
Infection Control Coordinator

Specialty Hospital Jacksonville
Jacksonville, FL

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Abstract

The long-term acute care hospital occupies a unique and challenging place along the continuum of healthcare services provided in the United States. Following an inpatient hospital stay, a large number of patients may still require acute, complex medical interventions and nursing care over an extended period of time. The long-term acute care hospital setting presents a dynamic challenge for the infection preventionist by congregating patients with a multitude of high-risk conditions, devices, therapies, and drug-resistant organisms for an average time span of 3 to 4 weeks. To elevate the challenge, there is limited long-term acute care hospital-specific research, a paucity of evidence-based interventions, and a general misconception regarding the long-term acute care hospital role in the postacute care constellation of healthcare options.[1]

Key Concepts

- Care of stable but chronically, critically ill patient population
- Resource-intensive, high-touch care over an extended period of time
- Multidrug-resistant organism transmission risks and resistance challenges
- High device utilization rates; care and maintenance challenges
- Antibiotic stewardship; extended antimicrobial treatment burdens
- Early recognition systemic inflammatory response syndrome and sepsis
- Research and evidence-based care strategies for the long-term acute care hospital setting
- Regulatory agencies and public reporting
- Environmental cleaning challenges

Background

For many patients, a deterioration from baseline level of function during their hospitalization means they cannot return directly to their homes or long-term care (LTC) facility at the time of discharge. For that growing segment, post-acute care providers are a crucial link to stabilization and recovery efforts. Postacute care providers include the long-term acute care hospitals (LTACH), skilled nursing facilities, inpatient rehabilitation facilities, assisted living facilities, home health companies, and nursing homes, all of which are also known as LTC.[1]

Congress created the LTACH as part of the Balanced Budget Act of 1997 in an attempt to facilitate prompt discharge for medically complex patients from a traditional acute care hospital in an effort to contain Medicare expenses.[2] An LTACH is very different from the other postacute care options. Initially, the goal was prompt discharge from an intensive care unit (ICU) for patients that were difficult to wean from a ventilator. Today, the LTACH population admission diagnoses cover a wide range of resource-intensive modalities, many of which are outside the scope of care provided by the other facilities and are too cost prohibitive to maintain in a traditional hospital setting.

To qualify as an LTACH for medical payment, a facility must meet the Centers for Medicare & Medicaid's (CMS) conditions of participation for acute care hospitals and have an average inpatient length of stay greater than 25 days.[3] CMS recognized 436 LTACHs in the United States in 2011.[3] Most LTACH facilities are freestanding but some are a hospital within a hospital (HWH), a facility located within the walls of a traditional hospital but functioning under an independent license with its own governing body.

In 2002, on the basis of the increase in Medicare costs and LTACH utilization, the prospective payment system (PPS) fee was instituted in an effort to decrease Medicare costs.[4] The CMS acute inpatient prospective payment system (IPPS) is used for acute care hospital inpatient stays. Under IPPS, each case is categorized into a diagnosis-related group (DRG) with payment weight assigned to it based on the average resources used to treat patients in that particular DRG.[5]

Despite the institution of PPS, the number of LTACHs continued to grow and Medicare expenses swelled exponentially, constituting 73 percent of the LTACH reimbursements.[2] As a consequence, Congress implemented a 3-year moratorium on all expansions and creation of new LTACH facilities,[2] unless an exception was applicable. A "25 percent rule" was legislated and limited the number of patients transferred to an LTACH, HWH, or satellite site from any single acute care hospital to 25 percent in any given quarter.[5] The moratorium was subsequently extended by the Patient Protection and Affordable Care Act and expired in December 2012.[6]

Basic Principles

PATIENT CHARACTERISTICS

Access to the LTACH is crucial for the relatively large percentage of severely compromised respiratory patients that are technology dependent. Many have undergone a tracheostomy after several failed attempts to wean from the ventilator during a typical stay in a traditional hospital. Patients may transfer directly from the ICU to the LTACH setting where the specialized care can continue over an extended

period of time. The LTACH average length of stay is 3 to 4 weeks in comparison to the average length of stay for a traditional hospital being only 5 to 6 days.[1] LTACHs achieve high rates of success in weaning and restoring patients to a higher level of independent function to allow them to continue on to other postacute care services.

Beyond ventilator weaning, patients admitted to the LTACH bring a variety of additional concerns with them from an infection control standpoint. Although considered medically stable, many patients arrive in fragile condition with compromised immune systems and may have any combination of the following:

- Recent history of sepsis/septic shock
- Extended antimicrobial therapy
- Multiple invasive devices
- High incidence of multidrug-resistant organism (MDRO) infections and colonization
- Frequent high-touch nursing care
- Immobility or limited mobility
- Complex wound/skin care management
- Ongoing hemodialysis for acute or chronic renal failure
- Targeted clinical nutrition management

Underlying comorbidities elevate the level of medical complexity and increase the LTACH patient's vulnerability to healthcare-associated infections (HAIs). Most LTACH patients have experienced prolonged hospitalization, many in an intensive care unit setting, which increases the risk of colonization or active infection with MDROs.[2] Patients are usually admitted to the LTACH from several different hospitals, nursing facilities, and even directly from home. Each referring facility may have MDROs with unique resistance patterns that combine in the LTACH setting with a highly vulnerable population—creating a mix of elements to challenge an infection prevention program.[2,7]

INFECTION PREVENTION AND CONTROL IN THE LTACH

As with all healthcare settings, Standard Precautions, Transmission-Based Precautions, and hand hygiene are crucial components to an effective infection prevention and control program in LTACHs. Early identification of MDRO or *Clostridium difficile* infection and colonization is imperative to limit the risk of transmission throughout the facility. One study compiled active surveillance data at the time of LTACH admission and found that 64 percent of patients were colonized with methicillin-resistant *Staphylococcus aureus*(MRSA), vancomycin-resistant *Enterococcus* (VRE), or both.[7]

COMMUNICATION

The LTACH setting demands a constant assessment of risks and a multidisciplinary approach to implement strategies to reduce HAI and transmission, both inside and outside the facility. Ongoing evaluation of interventions and strategies is crucial for safe and effective care and for the best patient outcomes. Because of the unique place the LTACH holds within the continuum of healthcare services, communication with referring facilities regarding detection of MDROs present on admission is important. Further communication with the local health department regarding increased MDRO activity, especially if unusual or extremely resistant patterns are observed, is another important aspect for regional evaluation and intervention. Transmission does occur in any healthcare setting but may not be identified until several cases come together in the LTACH setting. It is important to review cases for contributing

factors not only inside the facility, but also any similarities with referring facilities, transport companies, or any procedure types and locations in common from the hospitals of origin.

RISK ASSESSMENT

An annual risk assessment must be performed to determine the goals and objectives for the infection prevention and control program that takes into consideration the internal factors as well as the geographical location, the community, and the population it serves.[8] Because there are many risk factors present, it is important to identify the highest risk concerns and target efforts to specifically address those areas. Ongoing review throughout the year allows the infection preventionist (IP) to determine if the strategies are effective, if resources are being utilized in the most efficient manner, and for adjustment if another area needs more immediate attention.

Communication is vital for an effective infection prevention and control program for a facility. If the infection prevention and control committee (IPCC) structure is utilized, the members should represent a multidisciplinary team to address areas throughout the facility and have administrative and medical staff support. To be effective, the IPCC members should meet on a regular basis to review surveillance data, identify any areas of concern, plan interventions, define outcome measures, and review or develop policy.

Because there are numerous federal and state regulations, other committees may assist as the facility deems appropriate to meet their needs to identify and reduce risk of infections for the patients and healthcare personnel (HCP). Collaboration with the IP as the subject matter expert will help ensure the coordination of all activities related to surveillance, prevention, and control efforts throughout the facility. In all areas of infection prevention and control, knowledge of state and federal regulatory information and guidelines should be current and interventions proactive in the LTACH setting.

SURVEILLANCE

Surveillance is a key role for the LTACH infection preventionist and should be performed using solid epidemiological and statistical principles. The information from surveillance activities is an important component for risk assessment, interventions, and evaluation efforts for the infection prevention and control program as a whole. Methods for surveillance may vary based on the annual risk assessment findings and facility-specific needs.

With a whole-house approach to surveillance, all HAIs are monitored for the facility-wide population. However, an overall facility infection rate is not effective to identify contributing or causative factors in most cases. For example, this approach may be effective in identifying a certain MDRO by monitoring all positive cultures without regard to patient location or type of culture.

With targeted surveillance, rates are calculated for the particular HAI of concern and defined from a segment of the patient population. One example would be bloodstream infections identified in patients that have a central or peripherally inserted central line in place. Another example would be catheter-associated urinary tract infections (CAUTI) identified in the portion of the patient population with an indwelling urinary bladder catheter in use.

Surveillance data provides information to direct interventions and strategies based on level of risk. For example, if an increase in *C. difficile*rates is observed from the expected baseline or historical rates for the facility, interventions may be instituted. These might include environmental cleaning strategies. Initial rates would be compared to postintervention rates as a measure of success or to identify further opportunities for improvement.

If surveillance data reveal an increase in central line-associated bloodstream infections (CLABSI) or CAUTI from the expected baseline or above target surveillance goals, evidence-based strategies for line and device maintenance may be reviewed and implemented. Comparing outcome measures to surveillance data in evaluation efforts will determine if successful strategies have been implemented.

For more information, see **11. Surveillance**.

OUTBREAK INVESTIGATION

For infection transmission to occur, three elements must be present at the same time: a source, a susceptible host, and a mode of transmission. As previously discussed, LTACHs admit medically complex patients that have high prevalence rates of MDROs, require high-touch care, have high device utilization rates over extended time periods, and come from numerous acute care hospitals and postacute care services. Outbreaks are best prevented by the elements basic to an infection prevention and control program in all healthcare settings, which include comprehensive hand hygiene programs, Standard and Transmission-Based Precautions, with early identification and isolation measures in place.

In an event that either an outbreak or clusters of infection are observed, it is important for the IP to remember that the impact may not be limited to the facility itself and may have regional implications, as well. The LTACH may be first to identify organisms or infections of concern because patients are admitted from several different areas and locations. Outbreaks of MDRO-related infections tend to follow the flow of colonized patients across the span of healthcare services and institutions.[2] Admission cultures may identify previously undetected MDRO colonization or device-related infections and should be communicated back to the referring facility.

Communication with the local health department early in an outbreak—or with the detection of unusual microbe activity or resistance patterns, or in case clusters—is important to limit the impact and promote a positive outcome. In addition to processing state and locally mandated reports of communicable diseases, local health departments have the capability to view an outbreak situation from a much wider perspective and have the resources to request assistance on a larger scale as the situation may require.

For more information, see **12. Outbreak Investigations**.

PERFORMANCE MEASURES AND REGULATORY COMPLIANCE

Benchmark or comparative data among LTACH facilities has been limited by the voluntary nature of reporting elements to the data management systems, such as the National Healthcare Safety Network (NHSN) and third-party vendors. LTACHs are considered to be acute care facilities but provide care over longer time periods. Using comparative data from either acute care or LTC exclusively does not provide an accurate perspective for LTACH settings.

In 2008, NHSN added LTACH as a facility type to the reporting system for voluntary reporting efforts.[9] Prior to that time, LTACH data were only reported if an acute care hospital included the LTACH location as a specialty care area, so little was known regarding specific HAI rates or actual device utilization ratios.[9] Because there is little benchmarking data, many facilities use internal goals or historical data to formulate target goals for performance improvement activities.

Beginning in October 2012, LTACHs are required to submit data for three quality measures to CMS to avoid incurring a 2 percentage point reduction in the annual payment update.[10] Two of the three

measures require CLABSI and CAUTI data to be entered into the NHSN database.[11] As additional elements are added to mandatory reporting requirements for LTACHs, a reliable database of comparative data should emerge for the LTACH segment of postacute healthcare services.

ANTIBIOTIC STEWARDSHIP

Many patients are admitted to the LTACH setting to complete long-term antibiotic regimens that were started in the hospital setting. Active surveillance cultures on admission or cultures obtained in response to clinical evaluation may present challenges to the original treatment plan or necessitate a review for appropriate antibiotic use.

A 12-month study of 45 volunteer LTACHs produced a composite LTACH antibiogram. A criterion for the LTACH to be included in the study was that the facility's specific antibiogram be separate from the "host" hospital.[7] The study found that the median percentage of *Staphylococcus aureus* resistant to methicillin was 84 percent, *Pseudomonas aeruginosa* isolates resistant to fluoroquinolones was 60 percent, and *Enterococcus* spp. isolates resistant to vancomycin was 32 percent.[7]

C. difficile may cause a serious, diarrhea-inducing infection that is linked to more than 14,000 deaths in the United States each year.[12] Almost half of the infections occur in people younger than 65, but more than 90 percent of deaths occur in people 65 and older.[13] Almost all (94 percent) of *C. difficile* infections (CDIs) occur in people who recently received medical care, either inside or outside of a hospital setting.[13]

In about 20 percent of patients, CDI may resolve within 2 to 3 days of discontinuing the antibiotic to which the patient was previously exposed.[13] The infection can usually be treated with an appropriate course of metronidazole, oral vancomycin, or fidaxomicin. Repeat *C. difficile* testing is not recommended if the patient's symptoms have resolved, as patients may remain colonized and produce antigen for 6 to 8 weeks or longer.[14]

Discovery of additional resistance patterns, undetected MDRO infection or colonization, current renal function, recent use of multiple classes of antibiotics, allergies, and the potential impact of CDI for the patient all have a place of consideration in the individualized treatment plan. A multidisciplinary team approach is crucial to antibiotic management to promote appropriate use of antibiotics for the patient, the condition, and the microorganisms involved in a cost-efficient manner.

For more information, see **26. Antimicrobials and Resistance** and **72. Clostridium difficile Infection and Pseudomembranous Colitis**.

DEVICE UTILIZATION

Given the high prevalence rates for MDRO colonization and infections, another area of concern is the high device utilization rates among LTACH patient populations. For the traditional hospital setting, ventilator-associated pneumonia is the leading cause of death related to HAIs, exceeding the rate of death due to central line infections, severe sepsis, and respiratory tract infections in the nonintubated patient.[15] Many LTACH patients have been on the ventilator long enough to warrant a tracheostomy. They are not sedated, and may have resolved or improving pneumonia. Weaning efforts are based on individual tolerance levels.

Minimizing the use of indwelling devices and lines should be a first-line defense, if possible. Central venous catheters, including central and peripherally inserted central lines, are used to provide long-term venous access. Most bloodstream infections occur while a central venous catheter is in place.[16]

Indwelling urinary bladder catheters may be necessary for skin and wound healing, acute urinary retention, or accurate measurement of urinary output. A daily review of device and line indications helps to ensure that only the necessary indwelling devices and lines remain.

Once it is determined that the line or device is necessary, the concern changes to the best way to maintain it for the duration of use. Care bundles are strategies of interventions that when grouped together have clinical evidence of lowering infection rates.[16] Care bundles are typically developed for the acute care hospital setting, but device and line maintenance components can be easily adapted for use with the LTACH population.

Many patients arrive to the LTACH with the devices and lines already in place, leaving insertion practices, site selection, and subsequent care of the device prior to admission outside the facility's control. Therefore, maintaining the lines and devices with evidence-based guidelines becomes a crucial component for the infection prevention and control program. Audits for compliance with care bundle elements may reveal areas of opportunity for the IP to develop further recommendations or interventions.

For more information, see **34. Intravascular Device Infection**and **33. Urinary Tract Infection**.

EARLY RECOGNITION OF SYSTEMIC INFLAMMATORY RESPONSE SYNDROME (SIRS) AND SEPSIS

Sepsis is a progressive, life-threatening condition that occurs when bacteria enter a patient's bloodstream, causing a systemwide inflammatory response leading to overwhelming infection and multiorgan system dysfunction and failure.[17] The LTACH population is extremely vulnerable because of the numerous high-risk factors inherent to the patient population at large. Early identification and intervention can prevent sepsis from progressing to more lethal states, including severe sepsis with organ failure and septic shock with high mortality rates.

Recognizing early and subtle changes is important. Early clinical changes with SIRS may include a change in core temperature, respiratory rate, heart rate, as well as white blood cell counts which may be slightly outside the normal ranges.[17] Many other factors can also influence these clinical changes for the LTACH patient. However, if a source of infection is present, it would warrant further assessment for sepsis. Early, aggressive treatment can significantly increase survival rates.[18]

For the LTACH patient, the early identification and interventions within the facility's scope of practice can significantly impact the outcome for the patient and may even prevent further progression that would require a higher level of care, necessitating a transfer back to the acute care hospital setting. The severe sepsis care bundles were revised and updated in 2012 and, as a result, were modified into two, distinct, time-sensitive components. At the LTACH level of care, incorporating the elements within the 3-hour resuscitation bundle are well within the scope of practice, including measuring lactate levels, obtaining blood cultures, administering broad-spectrum antibiotics, and providing fluid resuscitation for hypotension to promote tissue perfusion.[18]

ENVIRONMENTAL CLEANING CHALLENGES

Another crucial area that must be considered for the LTACH is daily and terminal environmental cleaning and disinfection. Patients occupy rooms for 3 to 4 weeks and may carry MDROs or experience CDI during that time. Many high-touch areas exist in the patient's direct environment and may include items such as computer keyboards with in-room computer stations, telephones, TV remote controls, furniture, and the in-room privacy curtains. Transmission can occur from direct and indirect contact with the patient or with his or her immediate environment.

Patients placed into a room where there was a previous patient with a VRE, had a threefold risk of acquiring the same infection if there were positive environmental cultures. VRE acquisition was more than twice as likely when patients were admitted to rooms that had previously been occupied by VRE-colonized patients—either the immediate prior patient or any patients within the previous 2 weeks.[19]

Another study examined cultures from patient privacy curtains twice a week in two ICUs and a medical ward over a 3-week time span. Ninety-five percent of the curtains were contaminated at least once during the study period, including 21 percent with MRSA and 42 percent with VRE. Moreover, 92 percent of the contamination occurred within the first week following placement of a freshly laundered curtain.[20]Although not specific to the LTACH setting, both studies highlight the implications of an extended patient stay in combination with MDROs and a highly vulnerable patient population.

If present, *C. difficile*is shed in feces when the patient has a diarrhea-producing infection. Once the organism leaves the body and its vegetative state, a far more resistant spore form can exist for long periods of time, even years, in the environment. Any surface, device, or material that becomes contaminated may serve as a reservoir for the *C. difficile*spores that may be transferred on the unwashed hands of HCP, patients, visitors, or medical personnel who have touched a contaminated surface or item.[13]

A more resilient, epidemic strain of *C. difficile*has emerged in recent years known as North American pulsed-field Type 1 or NAP1.[12]The strain has spread widely after first being identified with outbreaks in Pittsburgh in 2000, Atlanta in 2001 and 2002, and Montreal in 2003. NAP1 appears more virulent, possibly due to increased production of toxins A and B, and an additional toxin known as binary toxin.[12]

At present, none of the tests approved by the U.S. Food and Drug Administration (FDA) differentiate between the various strains of *C. difficile*. Fortunately, because the control measures of any strain of *C. difficile*are similar, the identification of the specific strain is not imperative for controlling or preventing an outbreak situation.[13]

Patient care items and equipment should be dedicated or disposable. In the event equipment must be shared, such as lifts and weight scales, the item must be disinfected prior to use on the next patient to break the chain of infection and risk of transmission. Environmental cultures are not recommended outside of an outbreak situation or concern directly related to the environment. Items or equipment that are used for the care of multiple patients are obvious modes of transmitting pathogens by direct and indirect contact and need to be disinfected thoroughly before use with the next patient.

For more information, see **107. Environmental Services**and **72. Clostridium difficile Infection and Pseudomembranous Colitis**.

EDUCATION

Often, HCP overlook basic infection prevention and control measures because of a busy shift, high-acuity patients, and a seemingly endless task list each shift. However, education can promote compliance when employees comprehend the impact an HAI or MDRO transmission will have on the patient. HCP, ancillary department staff, medical staff, and visitors must understand the risk of transmission to the patient and their role in prevention efforts while interacting with the patient. The LTACH infection preventionist should use every opportunity to educate patients, staff, physicians, ancillary and transport staff, students, and visitors in the facility to infection prevention and control measures and the targeted rationale behind the strategies.

Family and visitors can play a significant role with HCP in reinforcing use of personal protective equipment (PPE), hand hygiene, and disinfecting items and equipment once they understand the direct implications for their loved one as a patient in a healthcare institution. Never assume that visitors are "refusing" to wear PPE or perform hand hygiene if they are observed in the room without it. Many times, visitors are unaware or do not fully understand the risk to the patient. Many family members feel that if they live with the patient, there is no risk to them personally. In the hospital setting, the visitor or family member is not who is likely to be the susceptible host, it is the patient—as unwashed hands and unprotected clothing enter their immediate environment with various MDROs or *C. difficile*spores with them.

Conclusions

The LTACH setting and patient population present a range of challenges for the infection preventionist. In every area, at every turn, risks of transmission and HAIs are present. Utilizing a multidisciplinary approach to implement strategies to reduce the risks is imperative to promote positive patient outcomes for the LTACH population.

As individual facilities demonstrate successful measures adapted to meet the needs of the population it serves, research will help build a foundation of evidence-based care bundles targeted to address the unique aspects found inside the walls of an LTACH setting.

FUTURE TRENDS

More research is needed to address this highly vulnerable population and the impact the LTACH setting makes throughout the healthcare continuum with patient care outcomes. As more patients require long-term acute care, issues will continue to evolve. Communication is a vital key in addressing those issues. Public reporting requirements should help generate reliable benchmark data for LTACHs.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Ophthalmology Services

Author(s): Darlene Miller, DHSC, MPH, CIC
Research Assistant Professor

Scientific Director-Microbiology Laboratory
Anne Bates Leach Eye Hospital
Bascom Palmer Eye Institute
University of Miami School of Medicine
Miami, FL

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Abstract

Healthcare-associated infections related to ophthalmic care are rare. In general, they make up less than 5 percent of infections in hospitalized patients. The incidence and prevalence of healthcare-associated infections in the majority of ambulatory centers are not known or uniformly monitored. Outbreaks of bacterial and viral conjunctivitis, contact lens-associated keratitis, and postoperative endophthalmitis are concerns that affect all infection preventionists across the continuum of healthcare. The widening scope of ophthalmic practice coupled with more advanced and complex outpatient procedures amplifies the number of patients at risk and increases the need for uniform infection prevention standards and routine surveillance.

Key Concepts

- The volume and complexity of ophthalmic procedures and patient care are expanding.
- More than 90 percent of ophthalmic services and patient care are offered in ambulatory settings.
- Ocular healthcare professionals and patients are at potential risk and exposure to several bloodborne pathogens and other infectious agents. These include human immunodeficiency virus, Hepatitis A virus, Hepatitis B virus, Hepatitis C virus, adenovirus, enterovirus, coxsackieviruses, severe acute respiratory virus syndrome, and Creutzfeldt-Jakob disease.
- Healthcare-associated infection rates in ambulatory settings are generally low, but outcomes can be catastrophic, leading to compromised vision and blindness.

- Adherence to basic infection prevention principles is required to protect patients and healthcare personnel from healthcare-associated ocular infections.
- Any organism gaining entry to the eye can establish infection.

Background

The scope and complexity of ophthalmic practice and patient care are expanding. Increasing antibiotic resistance, outbreaks with new or unusual organisms (nontypable *Streptococcus pneumoniae*, *Fusarium*, and *Acanthamoeba*) and emerging noninfectious adverse events (toxic anterior segment syndrome) require that infection preventionists and other members of the ophthalmic healthcare team be aware of common signs and symptoms of ocular infections and potential transmission risks to help prevent infections, improve patient safety, and preserve vision.

Healthcare-related ocular infections are thought to be rare. The consequences, however, can be catastrophic—leading to compromised vision and/or blindness.[1,2,3]No national surveillance program collects or monitors ocular infections in ambulatory settings.[1,4,5,6]

Patients at risk for ocular healthcare-associated infections (HAIs) are seen in a variety of healthcare settings. These include hospitals, stand-alone surgery centers, emergency rooms, urgent care and outpatient clinics, nursing homes, and physician offices. Services range from simple eyeglass fittings to complicated intraocular surgeries. Ninety-eight percent of these services are performed in ambulatory care or outpatient facilities. Opportunities for patient and staff exposure to infectious agents are numerous and include general eye examinations, removal of foreign bodies, contact lens fitting or removal, assessment of conjunctivitis and/or microbial keratitis, lacrimal lavage, removal of eyelashes, and assessment of patients with trauma, cataract, laser in situ keratomileusis (LASIK) surgery, and cosmetic surgery.[2,4,5,6]

Potential transmission and exposure risks include the presence of human immunodeficiency virus (HIV), Hepatitis B virus (HBV), Hepatitis C virus, and Creutzfeldt-Jacob disease (CJD) variant in ocular fluids and tissues. The risk, however, is usually low but also includes other viruses, bacteria, and protozoa (Table 63-1).[2,4,5,6]

Table 63-1 Exposure and Transmission Risks of Infectious Agents Associated with Ophthalmic Care

Virus	Disease	Reservoirs	Risks	Prevention
Adenovirus	Epidemic keratoconjunctivitis (EKC), keratitis	Hands of healthcare personnel (HCP)	High; numerous documented outbreaks in ambulatory and hospital, as well as community	Meticulous attention to hand hygiene. Soap and water and/or an alcohol-based sanitizer should be used prior to and after each patient contact. Wear gloves, exchange, and discard appropriately during outbreaks and when exposure to patient's tears or excretions is likely. Avoid shaking hands with patients with red/pink eye. Active patient and staff education on transmission prevention.
		Tears	High; isolated from tears, conjunctiva, corneal and intraocular fluids.	

		Contaminated equipment (tonometer tips ophthalmoscopes, slit-lamps, trial contact lenses)	High; isolated from tonometer tips and other ocular equipment	Use manufacturer's recommended disinfection protocols. The current Centers for Disease Control and Prevention (CDC) recommendations for disinfection of tonometer tips include a 5–10-minute soak in 3% hydrogen peroxide, 70% isopropyl or 70% ethyl alcohol, or in 5,000 ppm bleach. The are some reports that 3% hydrogen peroxide and 70% isopropyl alcohol may not be effective in eliminating adenovirus from equipment or the environment. 2% glutaraldehyde can be used to disinfect endoscopes (transmission).
		Contaminated medications	Low-moderate; adenovirus recovered from experimentally contaminated tips	Use single-dose vials only. If tip touches tears or mucus membrane, discard.
		Contaminated doorknobs, other environmental surfaces (desks, arms of chairs, etc.)	High; virus has been isolated from environmental surfaces up to 2 weeks.	Use an approved Environmental Protection Agency (EPA) environmental disinfectant. Clean environmental surfaces before patients, in between patients, and at the end of the day.
Coxsackievirus A, B	Same as adenovirus	Same as adenovirus	Low-moderate, documented in several outbreaks of conjunctivitis	Same as adenovirus
CJD	Creutzfeldt-Jacob disease	Corneal tissue	Low; documented three cases from donor rims	Use disposable patient care equipment and surgical gloves when exposure or contact with patient tears or conjunctival secretions is likely. Obtain adequate neurological history. Screen patients at risk for CJD.
Enterovirus	Same as adenovirus	Same as adenovirus	Low-moderate; several outbreaks of conjunctivitis	Same as adenovirus; enterovirus may be more resistant to 70% ethanol.
Hepatitis B	Viral hepatitis	Tears, corneal tissues, contaminated needles	Low; no documented cases	HCP should be immunized against HBV, 1:10 bleach for disinfection of semicritical equipment. Heat is used to sterilize equipment. Screen all corneal donors for infectious and bloodborne pathogens. Do not use tissue from positive donors.
HIV	Acquired immunodeficiency syndrome (AIDS), immunodeficiency syndrome	Tears; conjunctival, corneal, retinal tissues; intraocular fluids	Very low; no documented cases	At least 5–10-minute exposure to a fresh 1:10 bleach solution for disinfection of environment and semicritical equipment.
		Corneal tissue	Low	Screen donors for all bloodborne pathogens. Do not use tissue from positive donors.

Herpes simplex virus (HSV)	Blepharoconjunctivitis, keratitis, retinitis	Tears, vesicles, contaminated transplant tissues	Low; case(s) associated with infected corneal tissue, transmission in ophthalmic clinics from contaminated tonometer tips or hands of HCP	70% isopropyl alcohol is an effective disinfectant for HSV-contaminated tonometer tips. Screen corneal donors for the presence of HSV.
H1N1 (swine flu), H5N1 (Avian flu)	Conjunctivitis	Tears, conjunctival tissue	Very low; confirmed cases during outbreak	Staff and patients with exposure to influenza A or who present with flulike symptoms should be isolated or given an N95 respirator.
Rabies	Keratitis	Corneal tissue	Low; documented cases, eight after corneal transplantation	Detailed medical history is required to screen patients with infectious and neurological disease.

The external surface and intraocular structures are well protected (Figure 63-1). Structures are supported by local and systemic defense systems that provide a protective barrier against invasion by most microbes. Tears contain high concentrations of antibacterial proteins such as immunoglobulin A, lysozyme, and lactoferrin. In addition, the blinking action and constant flow of tears protect the eye from infection by removing bacteria and debris from the ocular surface. Cooler ocular surface temperatures also inhibit growth and survival of many microorganisms. Protection of ocular structures is also afforded by the anatomical arrangement that leaves the inner ocular structures well sequestered.[2,3]

Risk factors for ocular infections will differ according to age, sex, race, socioeconomic status, behavior, geographic location, occupation, and underlying chronic disease. Only a few organisms can penetrate the intact epithelium of the conjunctiva or cornea. Among these are *Neisseria gonorrhoeae*, *Neisseria meningitidis*, *Streptococcus pneumoniae*, *Listeria monocytogenes*, and *Corynebacterium diphtheriae*. For all others, a breach in the protective epithelial barrier or mucous membranes must occur. Once the intact epithelium has been breached (e.g., by trauma, or by insertion/removal of a contact lens), any microorganism gaining entrance can cause disease.[1,2,3]Whether an infection or damage occurs depends on (1) immune status of the host, (2) integrity of the underlying tissues, (3) virulence of the invading organism, and (4) the host's immune response.[1,2,3,7]

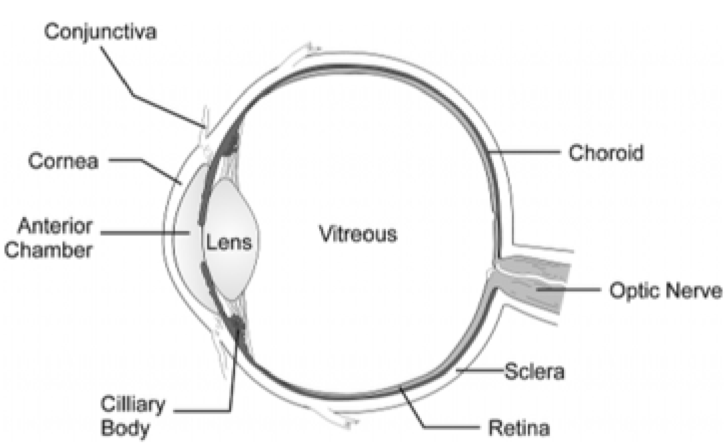


Figure 63-1.

Anatomy of the eye.

View Image

Acute bacterial and viral conjunctivitis occurs more frequently in children, whereas chronic disease occurs more often in elderly persons. *S. aureus* and *C. albicans*are common pathogens recovered from patients with keratitis in cooler climates, and *P. aeruginosa*and filamentous fungi are the causative agents recovered from patients in warmer climates or associated with

contact lens wearers. *S. pneumoniae*and *Moraxella*species are recovered from persons who habitually abuse alcohol or are homeless.[1,2]

This chapter provides current and applicable infection prevention and control information for healthcare personnel (HCP) involved in the care of patients with ocular disorders and infections.

KEY TERMS

Blepharitis: Inflammation and/or infection of the eyelids

Canaliculitis: Inflammation and/or infection of the canalicului

Conjunctivitis: Inflammation and/or infection of the conjunctiva-mucous membrane

Dacryoadenitis: Infection of the lacrimal gland

Dacryocystitis: Infection of the lacrimal sac

Endophthalmitis: Inflammation and/or infection of the intraocular fluids (anterior and vitreous) and tissues

Hypopyon: Presence of white blood cells in the anterior chamber

Intracameral: Injection of medications into the anterior chamber

Intravitreal: Injection of medications into the vitreous chamber

Keratoconjunctivitis: Inflammation and/or infection of the ocular external surfaces (conjunctiva and cornea epithelia)

Keratitis: Inflammation and/or infection of the surface or connective tissues of the cornea (window of the eye)

Optic neuritis: Inflammation of the optic nerve

Orbital cellulitis: Infection of the orbital soft tissues

Preseptal cellulitis: Inflammation of the periorbital soft tissues

Retinitis: Inflammation of the retina

Scleritis: Inflammation of the sclera (white of the eye)

Sterile endophthalmitis: Noninfectious inflammation of the vitreous and/or anterior chamber following intravitreal injections and/or surgery

Toxic anterior segment syndrome (TASS): Acute, sterile inflammation following anterior segment surgery

Uveitis: Inflammation of the iris, ciliary body, and choroidal tissues

Vitritis: Inflammation of the vitreous

Basic Principles

Ocular HAIs range from mild, self-limiting conjunctivitis and blepharitis to the more severe and sight-threatening conditions of orbital cellulitis, keratitis, and endophthalmitis. Infections of the external ocular surface, lids, conjunctiva, and cornea are more likely to be associated with HAIs transmitted via contaminated hands, fomites, or solutions, whereas infections of the intraocular chambers, lacrimal system, bony orbit, and soft tissues are most commonly associated with surgical interventions.[1,2,4,5,6,8]

Common ocular healthcare-associated pathogens and infections are outlined in Table 63-2.

Table 63-2 Common Ocular Healthcare-Associated Infections and Causative Agents (A)

Infection	Ambulatory Facilities	Hospitals	Nursing Homes	Physician's Offices	Community
Blepharitis	*S. aureus* (methicillin-resistant *S. aureus* [MRSA], MSSA)	*S. aureus* (MRSA, MSSA)	*S. aureus* (MRSA, MSSA)	*S. aureus* (MRSA, MSSA)	*S. aureus* (MRSA, MSSA)
Conjunctivitis	*S. aureus* (MRSA, MSSA)	Enteric Gram-negative rods	*Moraxella catarrhalis*	*S. pneumoniae*	*N. gonorrhoeae*
	S. pneumoniae	*P. aeruginosa*	*S. aureus*	*H. influenzae*	*N. meningitidis*
	H. influenzae	Adenovirus		*S. aureus*	*S. pneumoniae*
	Adenovirus			Adenovirus	*H. influenzae*
					C. trachomatis
					C. pneumoniae
					Rhinoviruses
Keratitis	*P. aeruginosa*	*P. aeruginosa*	*S. aureus*	*P. aeruginosa*	Contact lens-associated
	S. aureus		*Moraxella sp.*	*S. aureus*	*P. aeruginosa*
	Mycobacteria(refractive surgery)			Adenovirus	*S. aureus*
					Acanthamoeba
					Trauma associated
					Fusarium sp.
					Acanthamoeba
Endophthalmitis	*S. epidermidis*	*Candida albicans*	Endogenous	*S. epidermidis*	Traumatic
	S. aureus	*Aspergillus sp.*		*S. aureus*	*Bacillus sp.*
	S. viridans group				Coagulase-negative staphylococci
	E. faecalis	*S. aureus*			
		S. pneumoniae			

		S. viridans
	P. aeruginosa	
	Enteric Gram-negative rods	*Klebsiella sp.*
	H. influenzae	*E. coli*
		P. aeruginosa

CONJUNCTIVITIS

Conjunctivitis is generally defined as inflammation of the conjunctiva, which is a mucous membrane. Risk factors are varied and dependent on the underlying cause. Inflammation of the conjunctiva can be the result of an allergy, local or systemic infections, medications, and/or surgical intervention. "Pink eye" is a highly contagious infection and inflammation of the conjunctiva that most commonly occurs in the community. Etiological agents include bacteria, viruses, and—rarely—fungi (Table 63-3).[1,9,10]

Table 63-3 Primary Cause of Acute Conjunctivitis "Pink Eye"

Etiologic Agent	Top Pathogen	Age Group	Comments
Bacteria	*H. influenzae*	Preschool; usually under age 6	Highly contagious; children should be isolated for 24 hours after the start of therapy; otitis media usually accompanies this infection.
	S. pneumoniae	All ages; most frequent in preschool and school-age children	Usually associated with otitis media; has been associated with outbreaks in schools and dorms
	S. aureus	All ages; mainly adults	Increasing recovery of MRSA
Ophthalmia neonatorum*	*C. trachomatis*	Infants	Most common sexually transmitted disease (STD) in the United States; infants are infected after exposure in a contaminated birth canal; hyperacute discharge; may progress to keratitis and blindness.
	N. gonorrhoeae	Infants	Second most common STD in the United States; infants are infected after exposure in a contaminated birth canal; hyperacute discharge.
Viral	Coronaviruses; rhinoviruses	All ages; preschoolers and school-age children	Seasonal, most frequent etiology during cold and flu seasons
	Adenovirus	All age groups	Two syndromes: epidemic keratoconjunctivitis (EKC) and pharynoconjunctival fever (PCF); highly contagious; symptoms include tearing, pain, sensitivity to light, and a "gritty or sandy" feeling in the eyes, usually bilateral

*May also be caused by *S. aureus*and/or β-hemolytic streptococci.

Infections of the conjunctiva in ambulatory settings may be sporadic, but they more frequently present as outbreaks. Etiologic agents include bacteria, viruses, and fungi. Viral conjunctivitis, or epidemic

keratoconjunctivitis (EKC), is a common occurrence in ophthalmic physicians' offices or outpatient clinics. It is predominantly associated with adenovirus serotypes and can involve hundreds of patients and HCP. Enterovirus 70 or coxsackie A viruses may cause EKC but are more frequently associated with a similar illness, acute hemorrhagic conjunctivitis (AHC). Both conditions are highly contagious and easily spread via contaminated hands of HCP.[4,5,6,11,12]

Other reservoirs or vehicles implicated in outbreaks of EKC and AHC are contaminated office equipment (ophthalmoscopes, slit-lamps, tonometers tips, phoropters, trial contact lenses, and foreign body removal instruments), contaminated solutions (ophthalmic wash solutions, topical anesthetic), and towels.[4,5,6,11]

Tonometer tips are the most frequently implicated vehicle or reservoir. Tonometer are used to measure intraocular pressure. During examination, the tip depresses the cornea and may collect contaminated tears or corneal tissues and transmit infection to other patients or HCP. Adenovirus can survive for extended periods on hands and inanimate surfaces.[4,5,6,11]

The current Centers for Disease Control and Prevention (CDC) recommendations for disinfection of tonometer tips are to soak them for 5 to 10 minutes in 3 percent hydrogen peroxide, 5,000 ppm bleach, and 70 percent isopropyl alcohol and/or 70 percent ethanol. There is some debate as to whether 70 percent isopropyl alcohol or 3 percent hydrogen peroxide is effective in eliminating adenovirus.[13]During outbreaks of EKC or AHC, disposable tonometer tips should be used or the immersion time for cleaning the tonometers should be extended to 30 minutes. Current manufacturers' recommendations discourage immersion of tonometers into solutions.[4,5,6]

Few studies are available on conjunctivitis in hospitalized patients. Most reports are associated with outbreaks in neonatal intensive care units. Bacterial infections include *S. aureus*and coagulase-negative staphylococci. Gram-negative bacteria (*Klebsiella, Proteus,*and *Pseudomonas aeruginosa*) are more common in patients on ventilators.[1,10,14,15,16,17]EKC caused by adenoviruses are also common.[18]

Outbreaks of healthcare-associated bacterial conjunctivitis have also been documented in nursing homes and student health centers in colleges.[4,5,6,10,14,15,16,17,19]*S. aureus, Moraxella catarrhalis,* and *P. aeruginosa*are common pathogens recovered from patients in long-term care.[1,4,5,6,10,14,15,16,17,19]

Disinfection of the environment and equipment, along with frequent hand washing, are important infection prevention strategies to interrupt the chain of transmission of infectious pathogens in ambulatory and acute care facilities.[1,4,5,6,13]

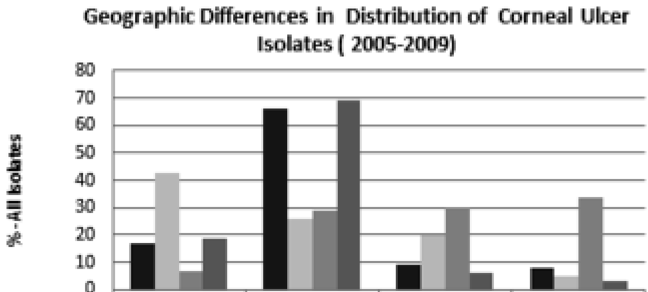
KERATITIS

Keratitis is the inflammation of the cornea—the clear dome at the front of the eye. Microbial keratitis is a true ocular emergency. Few organisms can invade the intact cornea. If the cornea epithelium is breached by trauma, insertion/removal of contact lens, or surgical intervention, organisms can enter, multiply, and destroy ocular tissue and structures. Organisms and their frequency vary by geographic regions (Figure 63-2).[2,20,21,22]

Figure 63-2.

Geographic frequency and distribution of microbial keratitis.

View Image



	Gram Negative Isolates	Gram Positive Isolates	Fungal Isolates	Parasitic Isolates
Brasil (N=1709)	17	66	9	8
Florida (N=1710)	43	26	20	5
India (N=585)	7	29	30	34
Spain (N=148)	19	69	6	3

From the 5th International Congress on Ocular Infection, February 2010. West Palm Beach Florida

In the United States, contact lens wear is a major risk factor for developing microbial keratitis. Incidence of contact lens-related keratitis ranges from 1.0 to 4.2 per 10,000 population (for daily contact lens wearers), to 2.7 to 36.8 per 10,000 population (for extended wearers).[23,24,25,26,27,28]Additional risk factors for microbial keratitis include trauma and refractive surgery.

More than 35,000 people in the United States wear contact lenses and the numbers are increasing.[23,24]Insertion and removal of contact lenses can cause a breach in the corneal epithelium and allow entrance and multiplication of microorganisms. Placement of lenses from contaminated contact lens cases can deliver high microbial loads to the corneal surface and stroma, which serve as excellent media for microbial proliferation and spread. Gram-negative rods (especially *P. aeruginosa*and *Serratia marcescens*) are the most common pathogens and can cause rapid corneal destruction within 24 hours. *S. aureus*and *Candida* spp. are also frequent pathogens. *Acanthamoeba*and other free-living amoeba and fungi are less frequent pathogens.[4,5,6,21]

Multistate outbreaks of *Fusarium*and *Acanthamoeba*associated with contaminated contact lens solutions highlight the need for infection prevention and patient safety education in ophthalmic centers. The *Fusarium*outbreak was worldwide and linked to contact lens cleaning and disinfecting solution. No direct link was established. The epidemic subsided, however, once the product was removed from the market. A change in preservative and the addition of substances to improve patient comfort were identified as possible risks for failure of the product to protect the contact lenses and lens cases from contamination by the fungus.[29,30]The multistate *Acanthamoeba*outbreak[31,32]was associated with disinfecting and cleaning solutions. No underlying problem or link was identified. Prevalence, however, also returned to normal levels after the product was recalled.[32,33,34]

Enteric pathogens and *P. aeruginosa*are common etiologic agents of keratitis in hospitalized patients, especially those on ventilators. Few studies, however, are available documenting the incidence and prevalence of HAI of the cornea in hospitalized patients.

The risk of HAIs following refractive surgery procedures in the United States is low. Frequency of HAIs following LASIK surgery (the most common procedure) range from 0.2 to 1.2 percent. More than 700,000 LASIK surgeries are performed in U.S. ambulatory centers annually.[35,36,37]Any microorganism gaining access to the modified cornea can cause infection. The most common pathogens include *S. aureus*and *Mycobacterium* spp. other than *M. tuberculosis*(MOTT).[35,38,39]Outbreaks following LASIK surgery have been traced to contaminated microkeratome blades, contaminated surgical instruments, water, and patients' ocular surface flora.

HCP who undergo LASIK or other refractive surgery procedures may be at increased risk for methicillin-resistant *S. aureus*(MRSA) infections.[35,39,40,41]

CORNEAL TRANSPLANT

More than 46,000 corneal transplants occur in the United States annually.[42,43,44,45]Although the risk is low, infections do occur. Wilhelmus and Hassan, in a study correlating endophthalmitis with positive corneal rims, reported a rate of 0.2 percent in 16,000 cases. In their review of HAIs after corneal transplantation, Durand and collegues reported three cases of CJD, two cases of HBV, eight cases of rabies, and one case of herpes simplex virus from donor to recipient.[1]

ENDOPHTHALMITIS

Healthcare-associated endophthalmitis, which can be infectious or noninfectious, is a rare but potentially devastating, vision-threatening complication following intraocular surgery, ocular trauma, or seeding via hematological spread from a systemic infectious foci.[1,2,8,46]Endophthalmitis is the inflammation of the intraocular fluids (aqueous or vitreous humor) and cavities.

Noninfectious endophthalmitis is an adverse event with several presenting etiologies, including retained lens material and other introduced toxic substances.[47,48,49]Frequency is unknown, but occurrence is not rare. Noninfectious postoperative endophthalmitis is most often associated with TASS. TASS, an acute, rapid onset of sterile anterior segment inflammation that mimics infectious endophthalmitis, most commonly occurs after cataract surgery.[50,51]It is important to differentiate between the two because treatment, management, and patient outcomes differ. Delay in making a correct diagnosis can lead to delay in appropriate treatment and could result in vision loss or blindness (Table 63-4).

Table 63-4 Common Ocular Healthcare-Associated Infections and Causative Agents (B)

	Toxic Anterior Segment Syndrome (TASS)	Infectious Endophthalmitis	Postintravitreal Injection Inflammation	Sterile Endophthalmitis
Incidence and/or prevalence	Sporadic, unknown, reduced since the 2006 national outbreak; May be increasing with increased intracameral injections of antibiotics and anti-inflammatory drugs	United States: dependent on type, range .01 for postcataract Europe: postcataract: other		
Site	Anterior chamber	Anterior and/or vitreous chambers	Vitreous chamber	Either intraocular chamber
Onset	12–24 hours	2–7 days	2–7 days	
Pain	Absence or mild to moderate	Severe	Mild to moderate	
Cornea edema	Limbus to limbus	Specific to area of trauma		
Intraocular pressure	Usually low, may increase suddenly	Usually not elevated		
Anterior chamber inflammation	Moderate to severe with increased white blood cells and fibrin. Hypopyon may be noted.	Moderate to severe. Fibrin may or may not be present. Hypopyon usually present. (75%)	Low, hypoyon and fibrin may be present.	
Vitritis	Rare	Always present		

Pupils	Fixed and dilated	Reactive	
Lid swelling	Not present	Present	Absence
Vision loss	Severe	Mild to moderate	Mild to moderate
Response to steroids	Rapid response with dramatic improvement	Mixed response	Mixed
Etiology	No single source. A variety of drugs, materials can initiate, including residual detergents, enzymes, or improperly rinsed, clean ophthalmic instruments. Culture and Gram stains always negative.	Organisms introduced at the time of surgery and/or trauma. Staphylococci, streptococci are the most common, usually from the patient's own skin flora. Culture and Gram stains usually positive. Also introduction of contaminated solutions and/or medications.	Retained drug?

Toxic, noninfectious reactions of the anterior chamber following intraocular surgery are not new. The presentation has been known for more than 25 years under various other names—postoperative anterior segment inflammation, sterile endophthalmitis, noninfectious endophthalmitis, toxic endothelium corneal diseases, and toxic endothelium cell destruction syndrome.[52,53,54] However, in 2006, a multicenter outbreak of TASS reemerged as a public health and patient safety issue. The outbreak was reported by more than 100 centers in North America.[50,55,56] No specific or single cause of the outbreak was identified.[55] During the investigations, cases were associated with breaches in handling, cleaning, and disinfecting of surgical instruments; introduction of contaminated solutions; contaminated intraocular lenses; toxic medications during surgery; and powder from gloves and irritants (dried blood, endotoxins, residual detergent) left on instruments.[56,57]

Surgical personnel and physicians must become aware of potential toxic hazards that may enter the eye during cataract surgery and implement appropriate strategies and recommendations as outlined by the American Academy of Ophthalmology (AAO), the Association of periOperative Registered Nurses (AORN), the American Society of Cataract and Refractive Surgeons (ASCRS), and the American Society of Ophthalmic Registered Nurses (ASORN) to reduce these vision-threatening, adverse patient events.[55,57,58,59] In a 2012 update on TASS, researchers documented a rate of 2.1 percent (1,454/69,000) from 130 questionnaires and 71 site visits.[57] They documented a continuing trend of poor instrument maintenance (47 percent), use of ultrasound baths without adequate cleaning (34 percent), and increased handling of intraocular lenses or instrument tips with gloved hands (21 percent). TASS remains a rare occurrence, but it is associated with significant ocular morbidity.[57]

Cases of noninfectious endophthalmitis following intravitreal injection of antivascular endothelial growth factor (anti-VEGF) agents such as bevacizumab, ranibizumab, and pegaptanib are increasingly being reported but are still rare.[60,61,62] These differ from TASS in time of onset (2 to 7 days) and inflammation involving both vitreous and anterior chambers, and they demonstrate limited endothelial damage and respond more slowly to corticosteroids. Sterile endophthalmitis after intravitreal injections has also been associated with triamicinolone acetonide, a steroid with antiangiogenic and antiedematous properties. Reported prevelance rates range from 0.20 to 6.73 percent. Symptoms are similar to those associated with anti-VEGF agents.[58,59,60,61,62] A few cases of sterile endophthalmitis have also been reported

following intravitreal injections of methotrexate for the treatment of primary central nervous system lymphoma.[60,63,64]

Infectious endophthalmitis is a rare but devastating complication following ocular surgery, penetrating trauma, intravitreal injections (exogenous), and/or hematological spread from an infected foci (endogenous).[1,27]It is an ocular emergency. Common signs include blurred or decreased vision, inflammation, and pain. Incidence is dependent on the type (Table 63-5).

Table 63-5 Classification of Infectious Endophthalmitis

Type	Common Pathogens
Postoperative	
Acute	Coagulase-negative staphylococci, *Staphylococcus aureus, Streptococcus*spp., Gram-negative bacilli
Delayed (> 6 weeks postop onset), chronic	*Propionibacterium acnes*, coagulase-negative staphylococci, fungi
Bleb-associated	*Streptococcus* spp.,*Haemophilus influenzae*
Posttraumatic	*Bacillus*spp. (30%–40%), *Staphylococcus*spp.
Endogenous	*Candida*spp., *Staphylococcus aureus*, Gram-negative staphylococci
Keratitis-associated	*Pseudomonas aeruginosa*, staphylococci
Intravitreal injection associated	Staphylococci, streptococci, fungi

Postoperative infectious endophthalmitis is most commonly associated with cataract surgery. In 2013, 3 million cataract procedures were performed in the United States with a success rate of 98 percent. Estimates are that by 2020, the number of cataract procedures will double. Ninety-eight percent of cataract surgeries are performed in ambulatory centers or outpatient departments. Historically, the incidence of endophthalmitis following cataract surgery ranged from 0.5 to 1 case per 1,000 procedures.[65,66]

Since the mid-1990s, there have been sporadic reports of increased HAIs following cataract surgery. Possible causes include increased use of clear corneal incisions and faulty wound closures. Lalwani and collegues, however, found no increase with clear cornea incisions.[67]Symptoms of postoperative endophthalmitis include decreased or blurred vision, pain, redness, light sensitivity, and, on occasion, vision loss if left untreated. Organisms are thought to be introduced at the time of surgery from the ocular surface (conjunctiva and lids), or via contaminated solutions or intraocular lenses. *S. epidermidis,*coagulase-negative staphylococci, and other Gram-positive pathogens are recovered most often.[1,2]

Endogenous (bloodborne) endophthalmitis is rare and has an incidence of 5 per 10,000 hospitalized patients.[66]Patients with comorbidities such as long-standing catheters, acquired immunodeficiency syndrome, cancer, diabetes mellitus, alcoholic hepatitis, or bone marrow transplants are at increased risk. *C. albicans*, *Aspergillus*spp., and other fungi are recovered in 50 percent of the cases. *S. aureus*, *S. pneumoniae*, *S. viridans*, and other *Streptococcus*spp. are typically isolated Gram-negative pathogens in these infections. *E. coli*, *Klebsiella* spp., and *P. aeruginosa*are causes of Gram-negative infections.[1,2]

INFECTION PREVENTION STRATEGIES

Infection prevention and patient safety efforts in ambulatory ophthalmic clinics and centers are similar to those in acute care facilities.[4,5,6] In addition, ophthalmic healthcare teams must develop and implement plans of action for prevention of HAIs and patient safety unique to ophthalmology. Standard Precautions apply and should be implemented across the continuum of care for all ophthalmic settings. Major concerns for ophthalmic HCP include hand hygiene, cleaning and sterilization of surgical and patient equipment, Isolation Precautions, contaminated medications, contaminated corneal tissue, and increases in needlestick/sharp injuries.

Hand Hygiene

Hand hygiene is the single most effective preventive measure in reducing and preventing infections. HCP in ophthalmology should adopt and follow the recommendations by the CDC or the World Health Organization (WHO) on hand hygiene. An approved antibacterial soap can be used for routine hand hygiene, or a waterless, alcohol-based product should be used to sanitize hands before and after every patient encounter or whenever they are visibly soiled.[68,69,70,71,72,73]

In a single-center study evaluating patterns of ophthalmologists hand hygiene, Aizman et al.[70] reported that physicians washed their hands between patients only 74 percent of the observed time. In another study evaluating hand contamination rates before and after patient encounters in an ophthalmic clinic, the authors recovered Gram-positive, Gram-negative, and fungal flora on hands of residents. Hand hygiene with alcohol-based hand rubs or chlorhexidine significantly reduced both resident and transient flora.[71]

Fingernails should be kept at a reasonable length. Artificial fingernails are not recommended because they can serve as a reservoir for the transmission of bacterial and viral infections. Hands and nails should be examined frequently for cuts and breaks to reduce the risk of infection (see **27. Hand Hygiene**).

Personal Protective Equipment

Latex and powder-free gloves should be available as part of ophthalmic HCP personal protective equipment and used when there is a risk of exposure to blood and other infectious body fluids. In general, gloves are not routinely used or required for routine ocular examinations except for known infectious patients and/or those with bloody tears.[4,5] Gowns, masks, and protective eyewear are not routinely used or required during routine ocular exams or procedures. They should be used as barrier precautions when there is a risk of exposures to contaminated aerosols, spattering or splashes of blood, or other contaminated fluids. N95 respirators should be worn during respiratory outbreaks or when there is a tuberculosis risk to protect patients and HCP.[4,5] Guidelines from the College of Optometrists in the United Kingdom indicated that surgical masks are not effective for protection and particulate filter masks (N95 respirators) should be worn to protect against airborne pathogens.[6] (See **28. Standard Precautions** and **29. Isolation Precautions (Transmission-based Precautions)**

Disinfection and Sterilization Protocol for Ocular Procedures and Surgical Instruments

Infection or injury to the eye can lead to permanent damage or compromised vision or result in long-term visual morbidity or blindness. HCP need to understand and adhere to disinfection and sterilization protocols for all ophthalmic and patient care procedures.

All ophthalmic surgical instruments must be cleaned, disinfected, and/or sterilized in accordance with manufacturers' directions for use (DFU) bolstered by recommendations from the AAO, ASCRS, AORN, and ASORN (Tables 63-6 and 63-7). In general, semicritical equipment such as tonometers and ophthalmoscopes can be adequately disinfected by use of a mild soap and/or immersion for 10 minutes or more in 3 percent hydrogen peroxide, 5,000 ppm bleach solution, and 70 percent isopropyl alcohol and/or 70 percent ethanol. Noncritical and environmental surfaces can be disinfected with an Environmental Protection Agency (EPA)-approved hospital disinfectant and/or sterilant.

Table 63-6 General Infection Prevention Practices in Ophthalmic Care Facilities

Item	Storage	Before Patient Encounter	After Each Patient Encounter
Dyes (Florescein)	Clean area(s)	Use single, individual strips.	Discard after use in biohazard container.
Dyes (ICG)	Clean area(s)	Mix with normal saline .9% solution draw-up in a sterile syringe.	Discard after use.
Gloves (must be powder, latex free)	Store in box.	Use gloves for all direct eye exams where hands will touch mucous membranes.	Dispose of gloves immediately after use. Use appropriate hand hygiene before and after using gloves.
Hands		Wash hands with soap and water and/or use an approved alcohol-based product before each patient exam.	Remove and appropriately discard gloves. Wash hands with soap and water after all examinations. Wash hands with soap and water after removal of gloves. An approved hand hygiene product can also be used.
		Keep fingernails clean and a reasonable length. Keep powder-free surgical gloves for use if hands or patient has exposed lesions.	Remove jewelry. Wet hands with water. Apply recommended amount of product to hands. Rub hands together vigorously for at least 15–30 seconds.
			Covering all surfaces of the hands and fingers. Rinse hands with water. Dry with disposable towel.
Head rests, chin rests, and brow bar	N/A	Wipe areas with 70% alcohol wipe before and after each patient. Perform through cleaning and disinfection once daily.	Wipe with 70% alcohol wipe/pad between patient and clean thoroughly once daily.
Eye drops (medication)	Store eyes drops in a cool dry area unless a certain temperature is recommended by the manufacturer.	Avoid contact or contamination of dropper tip with hands, patients' lashes, eyelids, or tears. Single-use eye drops are preferred and recommended.	Replace cap without hand touching dropper tip. Monitor and adhere to expiration dates.
	Label open drops with date and initials on bottle.		Discard if used on infected eye.
	Discard by expiration date or 1 month after opening as recommended by your institution policy and procedure.		

	Hold the cap in your hand during use.		
Water baths			Clean at the end of the day to prevent buildup of endotoxins and other toxic materials.
General environment		Basic environmental cleaning of counters, floors, chairs should be done at the end of each day with an approved hospital disinfectant.	Basic environmental cleaning of counters, floors, chairs should be done at the end of each day.
		A "red eye" or contaminated room should be designated to see patients with pink eye or known infectious disease.	Room should be cleaned with an approved EPA disinfectant after each patient.

Table 63-7 Common Ocular Healthcare-Associated Infections and Causative Agents (C)

Item	Storage	Level of Disinfection	Before each use	After each use
Diagnostic laser lens	Dry with lint-free cloth and store in dry case.	High-level disinfection with approved disinfectant. Manual cleaning/sterilization (ethylene oxide [EO]). Do not steam autoclave or soak these lenses.	Wipe clean with an alcohol pad. Inspect for damage (cracks) and evaluate function.	Wipe clean with an alcohol pad. Proceed with disinfection and/or sterilization (EO only). Store in a clean dry container at room temperature.
Foreign-body needles	Single-use 27-gauge hypodermic needle	High-level disinfection	Do not let needle come in contact with hands.	Discard in appropriate sharps container.
Fundus contact lens	Store in a clean closed container.	High level	Place lens in a contact solution; check date opened and expiration date of solution prior to use.	Fundus lenses should be cleaned with a mild cleaning solution after use then disinfected with 1:10 dilution of household bleach. Lens should be immersed in solution for 25 minutes.
				Rinse thoroughly with room-temperature sterile water, then dry with a lint-free cloth.
				Store in a sterilized closed contact lens container.
				Follow manufacturer's recommendations (DFU) for disinfection and care of lens and incorporate into your policy and procedure for cleaning, disinfecting ophthalmic instruments
Soft contact lenses	Individual sterile packing dry storage		Sterile one-time use	Discard lenses after use.
Trial disposable contact lenses	Individual sterile packing dry storage		Sterile one-time use	Discard lenses after use.

Contact lens trial cases	Dry storage	After receiving send for sterilization before use.	Discard cases after use.
Rigid contact lenses	Individual sterile packing dry storage	Disinfect between patients with heat and/or a hydrogen peroxide or chlorohexidene-containing disinfectant.	Follow manufacturer's DFU and your institution guidelines/policy and procedures for general care and disinfection/sterilization.
Gonioscopy lenses	Store in a clean closed container.	Place lens in a contact solution; check date opened and expiration date of solution prior to use.	Gonioscopy lenses should be cleaned with a mild cleaning solution after use then disinfected with 1:10 dilution of household bleach. Lens should be immersed in solution for 25 minutes (lakkis, Lian, Napper, and Kiely, 2007).
			Rinse thoroughly with room-temperature, sterile, water, then dry with a lint-free cloth.
			Store in a sterilized closed contact lens container.
			Follow manufacturer's DFU and your institution guidelines/policy and procedures for general care and disinfection/sterilization.
Lacrimal lavage probe (punctual dilator)	Central services sterile area	Keep sterile until use.	Spray with an enzymatic cleaner to prevent blood and protein buildup, rinse and place in ultrasonic cleaner, inspect, and sterilize.
Lacrimal lavage needle (cannula) (single use cannulas)	Central services sterile area	Keep sterile until use.	Spray with an enzymatic cleaner to prevent blood and protein buildup, rinse and place in ultrasonic cleaner, inspect, and sterilize.
Occluders/eye patch (tissue)	Store in the clinical area in a closed container	Wipe with 70% alcohol and use a piece of tissue as a barrier between occluder and eye patch.	Discard tissue and clean occluder with 70% alcohol after each use.
Ophthalmoscopes (direct. Mio, bio)	Store in the clinical area in a closed container	Wipe with 70% alcohol between patients.	Wipe with 70% alcohol between patients.
Phoropter/refractor head	Cover in a pouch and store in the clinical area	Wipe with 70% alcohol between patients.	Wipe with 70% alcohol between patients.
Scleral depressor, lid elevertors, specula, forceps	Central services sterile area	Keep sterile until use	Spray with an enzymatic cleaner to prevent blood and protein buildup, rinse and place in ultrasonic cleaner, inspect, and sterilize.
Stethoscopes	Cover in a pouch and store in the clinical area.	Wipe with 70% alcohol between patients.	Wipe with 70% alcohol between patients.

Tweezers	Central services sterile area	Keep sterile until use.	Spray with an enzymatic cleaner to prevent blood and protein buildup, rinse and place in ultrasonic cleaner, inspect, and sterilize.
Tonometers	Store in a clean closed container.	Wipe with 70% ethanol alcohol after each use.	General: clean with a mild cleaning solution after use then disinfect with 1:10 dilution of household bleach. Tonometer should be immersed in solution for 10 minutes. Rinse thoroughly with sterile water and dry with a lint-free cloth. Manual cleaning and soaking in sodium hypochlorite (5,000 ppm) for 1 hour and/or sodium hydroxide (5%) for 1 hour to reduce retention of corneal epithelial cells and the risk of CJD, variant Creutzfeldt-Jakob disease (vCJD).
Goldmann		Clean and disinfect after each patient's use.	Clean with a mild cleaning solution after use then disinfect with 1:10 dilution of household bleach. Tonometer should be immersed in solution for 10 minutes. Rinse thoroughly with sterile water and dry with a lint-free cloth.
Pneumotonometers		Use sterile disposable tonometer probe caps on pneumotonometers.	Discard probe after each patient encounter. Disinfect surface with 70% ethanol or 1:10 fresh bleach.
Tonopens		Use sterile disposable tonopen cover for each patient exam.	Discard tonopen cover in appropriate biohazard bag. Wipe down surface with 70% ethanol.
			Store in a sterilized closed contact lens container.
Schitoz		Tonometer should be disassembled between each use and foot pad and barrel cleaned between patient exams.	Clean with a mild cleaning solution after use then disinfect with 1:10 dilution of household bleach.
			Follow manufacturer's DFU and your institution's policy and procedures.
Slit-lamp microscope		The head rim and chin rest should be wiped with a disposable alcoholic pad between patients.	Wipe down chair with environmental cleaner at the end of the day.
Trial frames	Cover in a pouch and store in the clinical area	Wipe with 70% alcohol between patients.	Wipe with 70% alcohol between patients.

Conclusions

Few organisms can invade intact ocular structures. Once the ocular tissue is breached, however, any organism can enter, multiply, and establish infection. HAIs in ophthalmology are uncommon, but the consequences can be catastrophic—leading to compromised vision or blindness. The incidence and prevalence of ocular HAIs are not known. No national and few local surveillance programs are available for routine monitoring of ophthalmic infections. Hand hygiene, Standard Precautions, and appropriate disinfection and sterilization protocols can mitigate most infectious risks and improve patient outcomes.

Future Trends

ANTIBIOTIC RESISTANCE

Multidrug-resistant organisms such as MRSA, *S. pneumoniae, S. epidermidis,* and *P. aeruginosa* from HAIs are emerging pathogens among patients treated in ophthalmic ambulatory centers in the United States.[72,73] MRSA isolates have been recovered from patients with blepharitis, conjunctivitis, dacryocystitis, orbital cellulitis, and endophthalmitis and those who have undergone LASIK surgery.[74,75,76] We have observed a 34 percent increase in the prevalence of MRSA isolates recovered from patients presenting in our outpatient clinics over the last 10 years. Rates ranged from 31.6 to 48 percent, with an average of 31.9 percent. The increase in MRSA prevalence is of concern because these isolates are generally more resistant to the common ocular antimicrobials used for prophylaxis and treatment. Recent outbreaks associated with nontypable *S. pneumoniae* and emergence of resistance to levofloxacin is a concern for ophthalmic personnel. *S. pneumoniae* is among the most common pathogens recovered from pediatric conjunctivitis. It is also increasingly recovered from patients with keratitis and endophthalmitis.[15,72,77]

ENDOPHTHALMITIS

Both the Endophthalmitis Vitrectomy Study and the European Society of Cataract and Refractive Study confirmed that *S. epidermidis* and other coagulase-negative staphylococci are the predominant pathogens involved in postcataract endophthalmitis. Emerging resistance to the fluoroquinolones used for prophylaxis and treatment are disconcerting and further compromise limited therapeutic choices.[78,79,80,81]

COMPOUNDING PHARMACIES AND CONTAMINATED OCULAR PRODUCTS

Community compounding pharmacies provide a needed service for ophthalmologists and other ocular healthcare providers.[82,83] They prepare single-use doses from multidose vials, as well as combine and alter standard preparations to supply formulations that are not commercially available. More than 200 adverse events have been associated with more than 71 compounded products since 1990. Four (indomethacin, trypan blue, bevacizumab, and Brilliant Blue-G) products have been associated with 29 adverse events in patients undergoing ocular procedures.[84,85]

International Perspective

International ocular infection concerns in ambulatory centers and hospitals are similar worldwide. These include hand hygiene compliance, implementation and adherence to Standard Precautions, reduction of

postcataract infections, contact lens-associated infections, and emerging resistance. Infection rates are influenced by patient populations, difference in practice scope, climate, endemic pathogens, and antibiotic usage and availability. Implementation of infection prevention strategies should include adherence to WHO and/or CDC hand hygiene guidelines, use of personal protective equipment, and strict adherence to manufacturers' recommendations for cleaning, disinfecting, and sterilizing surgical instruments.[4,6]

Supplemental Resources

American National Standards Institute/Association for the Advancement of Medical Instrumentation. ST9:2006. Comprehensive guide to steam sterilization and sterility in health care facilities.

American National Standards Institute/Association for the Advancement of Medical Instrumentation. ST9:2007. Comprehensive guide to steam sterilization and sterility in health care facilities.

Association of periOperative Registered Nurses. Recommended practices for sterilization in the perioperative practice setting. In: Standards, Recommended Practices & Guidelines. Denver, CO: Association of periOperative Registered Nurses, 2007.

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Association of periOperative Registered Nurses (AORN). Recommended practices for sterilization in the perioperative practice setting. In: Association of Operating Room Nurses Standards, Recommended Practices & Guidelines. Denver: AORN, 2013.

Centers for Disease Control and Prevention (CDC). Guideline for Disinfection and Sterilization in Healthcare Facilities. 2008. Available at: **http://www.cdc.gov/hicpac/pdf/guidelines/Disinfection_Nov_2008.pdf**.

Preferred Practice Guidelines. Available at: **http://www.aao.org**.

KEY WEB SITES

American Academy of Ophthalmology. Available at: **http://www.aao.org**.

American Optometric Association. Available at: **http://www.aoa.org>**.

Association for the Advancement of Medical Instrumentation. Available at: **http://www.aami.org/standards**.

Association of periOperative Registered Nurses. Available at: **http://www.aorn.org**.

American Society of Ophthalmic Registered Nurses. Available at: **http://www.asorn.org**.

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Ambulatory Surgery Centers

Author(s): Mary Temple Post, RN, MS, CNS, CIC
Director, Infection Prevention

Oregon Patient Safety Commission
Portland, OR

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Abstract

Ambulatory surgery centers have become a popular alternative for surgical and other procedures that traditionally have been performed in hospital settings. The advance of technology, development of less invasive procedures, and new faster and more effective anesthetics have allowed for the cost-effective, safe delivery of these procedures outside of traditional settings.[1] As ambulatory surgery centers have evolved, increased regulatory oversight has followed. Infection prevention and control program infrastructure and compliance with nationally recognized guidelines are now required for ambulatory surgery centers by regulatory agencies.[2]

Key Concepts

- Ambulatory surgery centers are a distinct entity that operate exclusively to provide surgical services to patients who do not require hospitalization and are not expected to need to stay in a surgical facility longer than 24 hours.[3]
- A variety of invasive procedures, including endoscopy, dental, gynecological, ophthalmologic, orthopedic, pain, plastic or reconstructive, podiatry, neurosurgical, as well as otolaryngology may be performed at ambulatory surgery centers.[4]
- All ambulatory surgery centers are required by Centers for Medicare & Medicaid Services and state licensing agencies to have an explicit infection prevention and control program directed by a designated, licensed, qualified healthcare professional.[2]
- Infection prevention principles in ambulatory surgery centers do not differ from those practiced in inpatient surgical services.

- To ensure quality and safe patient care, ambulatory surgery centers must have infection prevention policies and procedures in place including evidence-based practices that follow nationally accepted infection prevention guidelines. Additionally, to deliver care in a safe environment, facilities are required to meet specific building requirements that are designed to prevent the transmission of infections.
- Monitoring patients for infectious complications such as surgical site infections in the ambulatory surgery center is a challenge because infections develop postoperatively after the patient has been discharged from the ambulatory surgery center. Therefore, the client with a surgical site infection often presents to a variety of different settings such as the physician's office, surgical clinic, or emergency department, complicating the surveillance methodology.[1]
- Despite the difficulties conducting surveillance and ensuring quality care in the ambulatory setting, ambulatory surgery centers are required to have infection prevention initiatives, including surveillance for infections, as a part of their quality assurance performance improvement program.[2]

Background

Ambulatory surgery centers (ASCs) were established more than 40 years ago when the first ASC was opened in Phoenix, Arizona, in 1970.[4] Reports indicate that there are more than 5,300 U.S. Medicare-certified ASCs which, since 2001, represents a growth of more than 54 percent. In 2007, at a cost of more than $3 billion, Medicare was billed for 6 million surgeries at these facilities.[4,5] According to the Centers for Medicare & Medicaid Services (CMS), 31 percent of ASCs are categorized as gastroenterology, 28 percent ophthalmology, 22 percent pain management, 8 percent orthopedic, 4 percent dermatology, and 7 percent other. Currently, 65 percent of ASCs are owned by physicians, 17 percent are a joint partnership between physicians and hospitals, 6 percent are owned by corporations established by hospital and physician partnerships, 6 percent are owned by corporations, 8 percent are corporations owned by physicians, and 2 percent are owned solely by hospitals.[4]

To be considered a "distinct entity" by CMS, ASCs are not permitted to share space with a hospital or critical access hospital outpatient surgery department. CMS does not allow the ASC and other entities, such as an adjacent physician's office, to mix functions and operations in a shared space during overlapping or concurrent hours of operations. However, CMS will allow two ASCs to share the same physical space, as long as they are not open at the same time and have separate operations, records, and so forth.[2]

To ensure safe care in these settings, the U.S. Department of Health & Human Services (HHS) included ASCs in the second tier of the *National Action Plan to Prevent Healthcare-associated Infections: Road Map to Elimination*.[5] In 2008, state survey agencies (SSAs) in Maryland, North Carolina, and Oklahoma piloted an infection control audit tool in 68 ASCs that was based on Centers for Disease Control and Prevention (CDC) guidelines and developed by CMS with input from the CDC. More than two-thirds of the participating facilities had lapses in infection prevention and control programs. More than 50 percent of the facilities had not undergone a regulatory survey in the past 5 years.[6] This finding led to the evaluation and revision of CMS's Conditions for Coverage (CfC)[3] for ASCs and the expansion of CMS's Infection Control Surveyor Worksheet to all CMS-licensed ASCs.[7] As a result of this activity, the

importance of infection prevention and control programs in ASCs was elevated and regulatory oversight improved.

Basic Principles

REGULATORY OVERSIGHT

To monitor infection prevention and control in ASCs, surveyors use a 15-page worksheet from CMS.[7] To establish compliance, information to complete the worksheet is obtained from observations, interviews, and document reviews. To observe facility practices, the surveyor will identify at least one surgical case and follow it from patient registration to discharge. A minimum of one surgical procedure must be observed during the site visit, unless the ASC is a low volume ASC with no procedures scheduled during the site visit. For facilities that perform brief procedures, such as colonoscopies or cataract surgeries, they will likely follow at least two cases.[2] SSAs or any one of four accreditation organizations (AOs) that have approved Medicare ASC accreditation programs have oversight to assure compliance with CMS CfC. ASC accreditation organizations include the Accreditation Association for Ambulatory Health Care (AAAHC), the American Association for Accreditation of Ambulatory Surgery Facilities (AAASF), The American Osteopathic Association (AOA), and The Joint Commission (TJC). If ASCs are "deemed" by an AO, they will be exempt from routine surveys conducted by SSAs and the AO will assume oversight for their compliance. However, if a complaint is filed or if a validation survey (to verify the equivalency of an AO's survey process) is required by CMS, the SSA may conduct a survey of the ASC.[2]

CMS's Infection Control Surveyor Worksheet collects information on the ASC characteristics (e.g., ownership; types and numbers of procedures that are performed at the ASC; number of operating rooms at the facility; the services provided at the ASC such as pharmacy, linen, sterilization/reprocessing and whether or not they are a contracted service; and the infection prevention and control program).[7]

Questions about the infection prevention and control program assess the program's infrastructure (e.g., staffing, selection and adoption of national guidelines for policies and procedures, surveillance processes, healthcare personnel [HCP] infection prevention training and education, employee health, and infection prevention and control program structure and function). Additionally, observations are made to assess the facility's infection prevention practices in hand hygiene, safe injections, sterilization and high-level disinfection, single-use devices, environmental hygiene, and point of care device handling, practices, and compliance. CMS's worksheet instructions indicate that any single breach in infection prevention, determined when performing interviews and/or observations, constitutes a breach for that practice.[7] When the worksheet was first introduced in 2009, funding was provided to allow CMS to survey one-third of nondeemed ASCs that year. Current funding allows CMS to survey 25 percent of nondeemed ASCs. Deemed ASCs are required to be surveyed by the AO every 3 years.[5] Although the Infection Control Worksheet is no longer required to be submitted to CMS, SSAs still use the worksheet during surveys and ASCs are encouraged to use the worksheet for their internal assessments on a regular basis.[2] The CMS Infection Control Surveyor Worksheet may be found at:

https://www.cms.gov/Regulations-and-Guidance/Guidance/Manuals/downloads/som107_exhibit_351.pdf.

ASC INFECTION PREVENTION AND CONTROL PROGRAM DEVELOPMENT

According to CMS, ASC must maintain an infection prevention and control program that seeks to minimize infections and communicable diseases. Components of the program must include the following:

- A functional and sanitary environment for surgical services
- Infection control guidelines based on nationally recognized standards and directed by a designated healthcare professional with training in infection prevention and control
- Integration into the ASC's quality assurance performance improvement (QAPI) program
- Ongoing, continuous processes and actions to prevent, identify, and manage infections and communicable diseases
- Mechanisms to immediately implement corrective actions and preventive measures that improve the control of infection within the ASC. [2]

The infection prevention and control program should have an infection risk assessment plan (ICRA) to identify and prioritize risks for infections, as well as a plan to prevent and control factors affecting the transmission of infections and communicable diseases. The ICRA should reflect the scope and complexity of services provided prioritizing high-risk, high-volume, and problem-prone areas. It should also consider the incidence, prevalence, and severity of problems in those areas, taking into account how they affect health outcomes, patient safety, and quality of care. This assessment identifies risks for acquiring and transmitting infections. Prior surveillance data findings, geographical risks, high-risk populations, procedures, new services, and other factors should be considered in the ICRA.

Based on identified risks, the ASC should develop an infection prevention plan with goals to minimize the possibility of transmitting infections. A written description of the methodology detailing data collection frequency, measures, and selection rationale should be included in the plan. The plan needs to include the orientation and education of all employees including the medical staff and HCP with ASC privileges and volunteers on the cause, transmission, and prevention of infections.

Performance improvement activities, findings, and corrective actions should be documented and shared with all HCP, including the surgeons. The infection prevention and control plan uses evidence-based guidelines and includes a written description of the following:

- Surveillance activities and how findings will be evaluated.
- The process for investigating outbreaks of infectious diseases.
- The integration of all components, functions, and activities of the infection prevention and control program.
- Method(s) to communicate concerns and findings to medical staff, employees, visitors, patients, and families.
- Mechanism(s) to report externally to other organizations such as the local health department. [2]

The infection prevention and control plan should be evaluated at least annually and when risks change significantly, to determine its successes and shortcomings, and to identify barriers. The findings of this process should be used to revise the plan.[2]

The ASC's governing body is responsible to oversee the functions of the infection prevention and control program. They should be involved with the annual infection prevention and control program evaluation and approval of the program ICRA, annual goals, and plan, including any changes made due to newly identified risks. They should review and approve all risk assessment documents. Often the governing

board will designate the QAPI to have continuous oversight for the infection prevention and control program. Thus, infection prevention activities should be reported to the QAPI at least annually and whenever there are changes to the plan with documentation included in the minutes of the QAPI.[2]

Additionally, results of the ICRA and the annual program evaluation should be shared with all medical staff and HCP.

CONSIDERATION OF NATIONALLY RECOGNIZED STANDARDS

The ASC is required to provide documentation that it considered and selected nationally recognized infection control guidelines for its program. This process may be included and documented in the development of the annual infection prevention plan. If it cannot provide such documentation, a deficiency related to 43 CFR 416.51 (b) must be cited by CMS, even if the ASC practices comply with generally accepted standards of practice/national guidelines. If an ASC is unable to provide such documentation and additionally does not comply with infection control standards of practice, the ASC will be cited for a condition-level deficiency related to 42 CFR 416.51.[7]

INFECTION SURVEILLANCE IN ASCS

There are no national estimates for the number of healthcare-associated infections (HAIs) that have originated in ASCs.[1]External benchmarking of ASC outcome data (i.e., surgical site infections [SSIs]) is challenging due to the diversity of procedures in which clear surveillance definitions are nonexistent. The ability for patients to seek treatment for adverse events or infections in other places including emergency rooms, physicians' offices, and hospitals complicates SSI surveillance even further. The ASC might not be aware of the development of an infectious complication and, thus, be unable to collect data on the SSI.[1]Currently, approximately 280 of more than 5,300 ASCs participate in the CDC's National Healthcare Safety Network (NHSN). Most of the ASCs that report SSI data to NHSN exist in one of the seven states that mandate reporting of SSI to the NHSN.[8]

A small number of outbreaks associated with ASCs have been reported. An outbreak of *Proteus mirabilis*SSIs, due to inadequately sterilized bone drills, occurred in patients who underwent podiatric surgery.[9]Four cases of endophthalmitis occurred following cataract surgery in an ophthalmology surgery center in 1993. Cultures of the humidifier water in the ventilation system yielded *Acremonium kiliense*, a fungus, which was phenotypically identical to the isolates cultured from the case patients.[10]In 2008, an outbreak of Hepatitis C virus involving an endoscopy ASC was reported. Over 50,000 patients identified in this outbreak were notified of the need to undergo postexposure testing. The source of the outbreak was attributed to syringe reuse (i.e., double dipping) and using contents from single-dose vials for more than one person.[11]

ASCs are required by CMS to perform active surveillance to track infections in patients. According to CMS, the ASC should document its monitoring/tracking activities, including the measures selected for monitoring, their methods for data collection, and their plans to analyze the findings.[2]Due to the brief, episodic care in ASCs, postprocedure infections will be identified postdischarge. Prior to discharge, patients should be educated to recognize signs and symptoms of infections and to contact the ASC to report them. To track infections, ASCs may involve their credentialed surgeons who will see the patients in their office postdischarge. However, there should be a mechanism in place to ensure that the results

of the follow-up are reported back to the ASC and documented in the patient's medical record.[2]

Strategies that ASCs can use to perform postdischarge surveillance include the following:

1. Phoning or sending emails or postcards to patients after their discharge inquiring if they developed an infection.
2. Including questions about infections in patient satisfaction surveys.
3. Sending postcards or emailing lists of patients undergoing procedures to their surgeon/provider requesting them to document if the patient developed infections and reporting them to the ASC.
4. Contacting the patient's primary care provider by phone or email to inquire if the patient developed a postprocedure infection.
5. Working with infection preventionists (IPs) in local hospitals or clinics to develop notification systems when patients are admitted to hospitals or seen in emergency departments or clinics with postoperative SSIs that might be associated with procedures performed at the ASC.
6. Reviewing daily ASC culture and lab reports from specimens submitted for possible infections that might be attributed to prior procedures performed at the ASC facility.
7. Reviewing daily operative schedules to identify patients undergoing incision and drainage (I & D) procedures that might be associated with prior surgical procedures.

Procedures with surgical site incisions may be followed for the development of SSIs. The CDC's infection criteria for SSIs should be applied. Ideally, ASCs should consider following NHSN methodology to identify, document, and calculate infection rates. This would include determining the level of infection (superficial, deep, organ/space) and following the procedures, as designated by NHSN, for either 30 or 90 days postoperatively.[12] Refer to **37. Surgical Site Infection**, for additional information. Even though ASC patients may not have procedures with surgical incisions, all patients should be followed for infectious complications. For example, gastroenterology patients may be followed for onset of fever, diarrhea, or hospital readmissions.

CMS is continuing to add quality measures to their reporting requirements.[13] In October 2012, CMS started to require ASCs to report the following quality measures:

1. Patient burn
2. Patient fall
3. Wrong site/side/patient/procedure/implant
4. Hospital admission/transfer
5. Prophylactic intravenous (IV) antibiotic timing

In 2013, CMS added the requirement for ASCs to report on their use of a safe surgery checklist and the volume of certain procedures they performed in 2012. Starting in 2014, ASCs will be required to report influenza vaccination coverage rates among HCP to NHSN for vaccines administered between October 1, 2014, and March 31, 2015.[13]

REPORTING INFECTIONS AND OUTBREAKS

ASCs should have policies and procedures for identifying, investigating, and reporting outbreaks. As required by their state, they should also have policies for reporting communicable diseases and they should maintain documentation of the diseases that have been reported. This includes not only infections or diseases in patients, but in HCP as well.[2] Refer to **12. Outbreak Investigations**, for additional information.

Infection Prevention Practices

STANDARD PRECAUTIONS

The implementation of Standard Precautions is essential to basic infection prevention practices in all patient care settings, including ASCs. Standard Precautions should be used for all patients regardless of their diagnosis. Standard Precautions include the following:

- Effective hand hygiene at all appropriate times
- Cleaning and disinfection of surfaces and equipment between patient uses
- Appropriate use of personal protective equipment (PPE) (e.g., gowns, gloves, mask, eye protection) for reasonably anticipated contact with body substances or contaminated equipment
- Safe injection practices
- Respiratory hygiene/cough etiquette
- Use of safety needless devices
- Safe handling of linens and waste
- Wearing masks for special lumbar puncture procedures[14]

Employees should be educated on and able to demonstrate appropriate utilization and application of Standard Precautions.[2] Staff should be knowledgeable about the indications for hand hygiene, including the situations when hand washing with soap and water, instead of waterless hand sanitizers, are required. Personnel involved in the direct care of patients undergoing surgical procedures should not wear artificial fingernails or nail enhancements.[15,16] Hand hygiene practices should be monitored and included in the QAPI program.[2] See **27. Hand Hygiene** and **28** for additional information on hand hygiene and Standard Precautions. Environmental hygiene and safe injection practices including processes for special lumbar procedures are discussed later in this chapter.

TRANSMISSION-BASED PRECAUTIONS

Standard Precautions apply to all patients and all situations, regardless of diagnosis or presumed infection status. In addition to Standard Precautions, Transmission-based Precautions are initiated when specific diseases/infections are suspected in an ASC patient.[14] Whenever surgeries are elective, patients who require Contact Precautions, Airborne Precautions, or Droplet Precautions should postpone their procedures until they are no longer contagious or be referred to an inpatient facility. ASCs are typically not prepared to provide care to patients in Transmission-based Precautions, particularly Airborne or Droplet Precautions.[16,17,18]

Screening patients for potential infections should begin when they are scheduled for their procedures. They should be asked if they have symptoms of active infections, such as cough, fever, rash, or new onset of diarrheal illness. A patient known to have symptoms of active infection not related to the underlying diagnosis and indication for the surgical procedure should be rescheduled for the surgery or procedure unless the surgery is deemed emergent.[17,18]

Patients should be asked if they have a medical history of methicillin-resistant *Staphylococcus aureus* (MRSA) or another type of multidrug-resistant organism (MDRO) infection. Although patients with MDRO colonization may be scheduled for surgery in ASCs, the surgeons of patients identified with an

acute, active MRSA or MDRO infection should be consulted to determine if they would like to have the surgical procedure rescheduled until the active infection has cleared. It is not necessary to schedule patients with MDRO colonizations/infections as the last case of the day.[19]

Supplies for respiratory hygiene/cough etiquette (tissues, masks, hand sanitizers) and instructions for use should be available at the reception area for those patients and visitors who present with a cough or coldlike symptoms. Reception room staff should be educated to be alert to patients and significant others presenting with symptoms of infection. If concerned, they should notify clinical HCP of their observations to enable rapid placement into a designated exam room or room with a closable door until the physician and/or clinical HCP can further evaluate the situation. Patients suspected of having signs and symptoms of respiratory illness should be given a mask and placed in a room with the door closed until transfer for additional treatment at a receiving facility or discharge to home can be done. A negative pressure room is preferred for placing the patient, although most ASCs will not have access to a negative pressure room. If others accompanying the patient exhibit signs and symptoms of infection, they should be asked to wait somewhere other than in the facility after arrangements for the patient to be picked up for transport home are made. For airborne isolation, the room used by the patient should not be used for an hour after the patient has left the room. If the patient has symptoms of an airborne illness, the HCP should wear a barrier mask at a minimum, but an N95 respirator is preferred during exposure time to the patient.[14,17,18]

The following more common infections are listed with type of isolation indicated. Refer to the CDC's *Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Health Care Settings* [14]for further information on isolation category requirements or to **29. Isolation Precautions (Transmission-based Precautions)**.

Tuberculosis: Airborne

Chickenpox: Airborne, use Contact Precautions as well if contact with active lesions is anticipated or to handle used linens.

Measles: Airborne

Mumps: Droplet

Rubella: Droplet

Bacterial meningitis: Droplet

Pertussis: Droplet

When plans are made to transfer a patient to another facility, the ASC will notify the receiving facility of any potentially infectious disease so that appropriate precautions may be implemented. ASC staff should implement appropriate barriers specific to the situation prior to transport (e.g., mask on patient, wound covered) and advise the persons doing the transport of these precautions.

Patients with potential transmissible illnesses spread by contact or droplet routes should be segregated (at least 3 feet away) in the waiting area if an exam room is unavailable. All patients should have any open wounds covered with an impermeable dressing that is clean and dry.

MANAGEMENT OF PATIENTS WITH MRSA OR OTHER MDROS IN AN ASC

Patients identified as having active or recent infections with MRSA or other MDROs should have such noted on their presurgical health history form. ASCs should have an identification system in place to notify other care providers (e.g., placed in the electronic medical record, MDRO noted on the chart, laminated card with MDRO placed on the patient chart, MDRO written by patient's name on surgery white board the day of surgery).[20]

Use Standard Precautions at all times for patients known to be infected or colonized with target MDROs, making sure that gloves and gowns are used for contact with uncontrolled secretions, pressure ulcers, draining wounds, stool incontinence, and ostomy tubes and bags. Barrier masks with shields are indicated when performing splash-generating procedures. If possible, consider a private room or spatial separation of patients with potentially active MDROs. Shared patient care equipment and surfaces (e.g., gurney, blood pressure cuffs, oximeters) should be cleaned and disinfected with an Environmental Protection Agency (EPA)-registered agent before reuse. Note: An EPA-registered disinfectant with a *Clostridium difficile*sporicidal claim should be used to disinfect items used by patients with diarrhea, particularly those with known or suspected *C. difficile*infections. Before use, care should be taken to ensure disinfected equipment is compatible with the disinfectant solution (see manufacturer's guidelines for cleaning and disinfection).[21,22]

SURGICAL SITE INFECTION PREVENTION

HCP in ASCs should maintain practices recommended by nationally recognized infection control guidelines and, in general, not vary from those used in inpatient surgical services. Policies and procedures should document references for aseptic technique and maintenance of the sterile field. Depending on the type of procedure, sterile gloves, sterile gowns, and sterile drapes and drape accessories that extend the sterile field to include covering additional furniture or equipment may be required. Appropriate attire, including freshly laundered scrubs, clean shoes, and hair covering are worn in semirestricted and restricted zones in the operating room. Masks should be worn in restricted areas when sterile trays have been opened. HCP should be oriented to the appropriate surgical scrub and surgical hand rub procedures and adherence to those protocols should be monitored. Promotion and monitoring of hand hygiene among staff and employees, including utilization of alcohol-based hand sanitizers, use of appropriate antiseptic agent, and technique for skin preparation, should be performed.[19,20]

ASCs should mitigate risks of infections through the implementation of protocols to ensure that antibiotic prophylaxis to prevent SSI for appropriate procedures is administered at the appropriate time, done with an appropriate antibiotic at the appropriate dose, and discontinued appropriately after surgery.[2]Other

evidence-based practices to mitigate risks of infections include removal of hair, if needed, with clippers or a depilatory agent, use of adequate bowel preparations and antibiotics, maintenance of normothermia, minimizing operating room traffic, treating infections before the elective procedure, following wound dressing protocols including the use of sterile dressings for 24 to 48 hours postoperatively, maintaining glucose control, following appropriate maintenance of a clean and sanitary environment, and/or considering nasal screening and decolonizing only *Staphylococcus aureus*carriers undergoing elective cardiac and other procedures with implants (e.g., orthopedic, neurosurgery) with preoperative mupirocin therapy.[23]

A critical component of infection prevention is to ensure patients, visitors, and HCP, as appropriate, are educated about infections and communicable diseases and methods to reduce transmission in the ASC and in the community. Postdischarge instructions should include appropriate care of the surgical site

incision postoperatively as well as the signs and symptoms of potential infections, who they should notify of their concerns and when they should notify their providers.[20]

Refer to Chapters **37**, **37**, **55**, and **68**for additional information on surgical site infections, aseptic technique, endoscopy, and surgical services.

Sterilization and Disinfection Practices

Implementation of appropriate sterilization and disinfection practices are critical to the prevention of infections in surgical settings. All individuals involved with the handling and processing of reusable equipment should be trained and able to demonstrate competency during orientation and annually thereafter. Documentation of training should be maintained in the employee's personnel file, as well as in the area where cleaning and disinfection is conducted. Continuing education (including training for all new instrumentation, devices, and equipment) should be conducted at regular intervals. A quality control program is important to ensure appropriate disinfection and sterilization.[2,20,21]

All reusable instruments, equipment, and used surfaces should be decontaminated, disinfected, or sterilized prior to use on a patient. The infection control guidelines, including manufacturer's directions, for cleaning, disinfection, and sterilization of patient care equipment, instruments, and the patient care environment must be followed. Manufacturer's directions and facility policies and procedures for reprocessing reusable instruments and equipment, including directions for use of the reprocessing equipment (i.e., sterilizer, tunnel washers, etc.) should be available to staff at all times. Documentation should be kept on the maintenance of the reprocessing equipment following manufacturer's directions.[2,20,21]

Personnel should wear clean scrub attire and should wear a fluid-resistant cover gown (tied in back) and heavy-duty gloves during the decontamination process. All head and facial hair needs to be completely covered with a surgical-type hair covering. Masks and goggles or a face shield to protect against splashes or sprays should be worn. Staff should always follow the hand hygiene policy.[2,20]

The ASC should have protocols for the use and documentation of mechanical (physical), chemical, and biological monitors to ensure that the sterilization process has been effective. Policies on management of positive biological indicators and recalls should be developed and included in the staff training. Policies should be in place for the release of implants prior to biological indicator results. Additionally, ASCs should have policies and procedures for immediate-use sterilization and to ensure that loaner instruments obtained from other facilities or from a vendor are processed according to the manufacturer's instructions before surgery and before they are returned.[20,24,25]

ASCs should provide guidelines for the safe cleaning and reprocessing of soiled endoscopes and associated equipment to reduce the risk of HAIs as well as to provide a safe environment for patients and HCP. All endoscopes are to be cleaned and high-level disinfected or sterilized (based on practice application) according to the manufacturer's directions.[21,26]Also refer to **31. Cleaning, Disinfection, and Sterilization**.

Only individuals who have successfully completed their training and competency assessment should be allowed to independently reprocess endoscopes without supervision. Training programs should review

safe handling procedures for all chemicals used to reprocess the endoscopes. This training should include:

- Appropriate PPE to use
- Appropriate ventilation requirements and/or use of ventilation equipment
- Hazardous chemical labeling, chemical storage, disposal and spill handling requirements
- Appropriate chemical mixing instructions and required soak times
- Determination of solution expiration date and appropriate labeling of solution containers and bottles with those dates
- Appropriate procedures to follow for testing solution minimum effective concentration and the documentation of those results
- Procedures to validate and record the testing of the chemical concentration test strips and the labeling of the expiration date on the test strip vials

  Staff should be trained on the cleaning processes for each endoscope or item requiring high-level disinfection, including, as appropriate, precleaning procedures; leak tests; visual inspection; cleaning all values, biopsy ports, and channels with the appropriately sized brush; disinfection of the scopes with the appropriate high-level disinfectant; attaching appropriate automatic endoscope reprocessor; safety precautions (use of eye wash station, disposal of chemicals, and spill cleaning procedures); cleaning connectors to the scope; and rinsing, drying, and storage of all endoscopes or other equipment.[21,26]

According to U.S. Food and Drug Administration (FDA) guidelines, ASCs should not reprocess single-use devices. Instead, they may contract with an FDA-approved vendor to reprocess FDA-approved single-use devices approved for reprocessing.[27,28]For additional information, refer to **32. Reprocessing Single-Use Devices**.

Safe Injection Practices

Safe injection practices have become a new component of Standard Precautions due to reports of infections spread by inappropriate handling of injectable medications. A major Hepatitis C outbreak in an ASC was attributed to inappropriate medication handling.[11]In a survey of 68 ASCs, Schaefer et al. found that 28 percent were using single-use vials for more than one patient and 46 percent were not following recommended practices for the safe handling of blood glucose monitoring equipment.[6]Since that time, attention has been paid to addressing these concerns in the CMS infection control worksheet used by surveyors.[7]

The following recommendations should apply to the use of needles and syringes, cannulae that replace needles, single-dose and multidose vials, and, where applicable, intravenous delivery system:[14,29,30,31]

- Perform hand hygiene prior to accessing medications and solutions and immediately before drawing up or administering the medication.
- Check expiration dates prior to administration.

- Use aseptic technique to avoid contamination of sterile injection equipment; the stopper on vials or IV tubing ports or connectors shall be scrubbed with alcohol (or other products if appropriate) prior to each entry.
- Many eye ointments and eye drops are now available in single-dose or smaller sized containers. If using multidose eye drops:[29]
  - The bottle tip should not come into direct contact with the patient's tears or conjunctiva; if the tip does touch the patient, the bottle must be discarded.
  - Discard the bottle when used on patient with an infectious eye disease.
- A single needle and single syringe are used for a single patient.
  - Do not administer medications from a syringe to multiple patients, even if the needle or cannula on the syringe is changed.
  - Needles, cannulae, and syringes are sterile, single-use items; they should not be reused for another patient or to access a medication or solution that might be used for a subsequent patient.
  - Medication vials are always entered into with a new needle and new syringe regardless of whether that medication vial is dedicated for that patient only and is being used for the same procedure.
- Use fluid infusion and administration sets (e.g., IV bags, tubing, and connectors) for one patient only and dispose of appropriately after use.
  - Consider a syringe or needle/cannula contaminated once it has been used to enter or connect to a patient's IV infusion bag or administration set.
  - Spike IV or irrigation bags/containers no sooner than 1 hour prior to initiation of administration.
  - Do not use bags or bottles of IV solution as a common source of supply for multiple patients (e.g., saline flushes).
- Use single-dose or single-patient use vials for medications whenever possible.
  - Do not administer medications from single-dose vials or ampules to multiple patients or combine remaining contents for later use.
  - Discard vials or solutions labeled with "single patient use" or "single use" or "preservative free" after use on single patient.
  - Manufactured prefilled syringes that may have enough medication for more than one patient must still only be used for one patient and discarded at the end of the procedure.
- Multidose injectable vials are only used for one patient, whenever possible.
  - If multidose vials must be used, both the needle or cannula and syringe used to access the multidose vial must be sterile.
  - Multidose containers (e.g., vials, eye drops) are formulated for removal of portions on multiple occasions because they contain antimicrobial preservatives. The beyond-use date after initially entering or opening (e.g., needle-punctured) multidose containers is 28 days, unless a shorter or longer time frame is otherwise specified by the manufacturer.
  - Multidose vials used for more than one patient should be stored and accessed away from the immediate areas where direct patient contact occurs; store in accordance with the manufacturer's recommendations and discard if sterility is compromised or questionable.
- Draw up medication just prior to the procedure.
  - Do not draw up for multiple patients.
  - Predrawn medications must be labeled properly with the date and time of the draw, initials of the person drawing up the medication, name of the medication, strength of the medication, and the discard date and time.

- Sharps should be disposed of in a puncture-resistant sharps container.
- Never store or carry medications in personal clothing or pockets.

Safe Blood Glucose Monitoring and Point of Care Device Handling

Outbreaks have been reported related to the sharing of blood glucose monitoring equipment between patients.[32] For example, viral hepatitis outbreaks have been reported due to unsafe blood glucose monitoring practices.[33,34,35,36,37] It is important that all members of the healthcare team comply with current CDC and American Association of Diabetes Educators (AADE) recommendations for the prevention of transmission of bloodborne infectious agents during blood glucose monitoring and other point of care testing. Disposable single-use, autodisabling lancets should be used when performing fingersticks in the ASC. Whenever possible, blood glucose meters should be assigned to an individual person and not shared. If a manufacturer indicates that it can be used on multiple patients, thoroughly clean and disinfect it after each use according to the manufacturer's recommendations with an EPA-approved disinfectant. Insulin pens should not be shared between patients.[32,38]

Special Lumbar Procedures

In 2004, the CDC investigated eight cases of postmyelography meningitis that were caused by streptococcal species consistent with oropharyngeal flora. The Healthcare Infection Control Practices Advisory Committee (HICPAC) reviewed the evidence from this investigation and several others and concluded that during lumbar procedures, face masks should be worn by the individual placing a catheter or injecting material into the spinal or epidural space.[14] These recommendations apply not only in acute care settings such as hospitals, but in any setting where spinal injection procedures are performed, such as outpatient imaging facilities, ASCs, and pain management clinics. For other spinal procedures (e.g., diagnostic and therapeutic lumbar punctures) or handling of devices to access the cerebrospinal fluid (e.g., Ommaya reservoir), there is limited evidence of a similar risk. At a minimum, HCP should use aseptic technique and follow safe injection practices (e.g., dedicating single-dose vials to single-patient use) for these procedures; a face mask can be considered as an additional precaution.[39]

Maintenance of a Sanitary Environment

The ASC must provide a clean and sanitary environment for the provision of surgical services to prevent environmental sources of infections and communicable diseases.[2] All areas of the ASC facility should be maintained in a state of cleanliness that meets professional standards in order to protect patients and HCP from potentially infectious microorganisms. This includes the waiting area(s), the presurgical prep area(s), the recovery room(s), the procedure or operating rooms, instrument and equipment reprocessing areas, floors, horizontal surfaces, air inlets and ventilation ducts, patient equipment, mechanical rooms, supply, storage areas, etc. Procedures should be in place for the cleaning of floors and furniture in the ASC. It is highly recommended that furniture and flooring be made of

nonabsorbable, easy-to-clean materials to minimize infection transmission.[22]The facility should use a hospital-grade EPA-registered disinfectant/detergent approved by the committee overseeing the functions of the infection prevention and control program. Appropriate pest control measures should be in place. Food sanitation processes should be followed for employee food storage and eating areas.[2,20,21,22]

Environmental cleaning is a team effort. Personnel responsible for cleaning the environment and equipment need to receive education and training on proper environmental cleaning and disinfection methods, agent use and selection, and safety precautions according to Occupational Safety and Health Administration (OHSA) guidelines. Attention to high touch surfaces (e.g., light switches, door handles, bedrails) is essential. Specialized medical equipment as well as electronic computer screens, keyboards, and other accessories may have special requirements regarding the types of chemicals that can be used for their disinfection. All surfaces in the operating or procedure rooms need to be disinfected as appropriate. ASCs should consider the use of keyboard covers or other protective devices that can cover and protect the equipment yet can be disinfected according to established standards.[20,21,22,40,41]

The ASC should have procedures in place for the preparation, visual inspection, and damp-dusting of the operating room at the beginning of the day. Procedures should be in place for the routine cleaning between cases as well as for terminal cleaning at the end of the day. Staff should receive training on room turnover procedures and their specific assignments (e.g., anesthesia tech roles, circulator role, etc.). It is important to emphasize that room turnover procedures should not be compromised in order to maintain a specified surgical schedule. HCP should demonstrate competency in performing the cleaning processes after their training.[2,20]

Policies and procedures should be in place for handling and disposing of regulated and nonregulated waste, including rigid sharps containers. These policies should comply with any applicable federal, state, and county regulations. PPE must be worn according to the OSHA Bloodborne Pathogen Standard when disposing of waste that could result in exposure to bloodborne or other potentially infectious microorganisms and hazardous material.[20,21,22,42]

The ASC should have policies in place for cleaning blood spills. Blood spills may be cleaned using an approved blood spill kit. The spill kit manufacturer's recommendations for cleaning and decontaminating the spill should be followed. As an alternative, a fresh 1:10 dilution of bleach may be used. Gloves and other appropriate PPE (based on the specific situation) need to be worn.[42](Refer to **105. Minimizing Exposure to Blood and Body Fluids**.)

Note: If a blood spill kit is used, the disinfectant should be EPA-registered and have kill data against Hepatitis B and HIV and should be tuberculocidal. Blood spill kits have expiration dates that must be monitored.

Surveyors will interview staff to determine their knowledge of cleaning and disinfection procedures and schedules. Additionally, they will ask for documentation to confirm the information they have received from interviews.[2]

EVALUATING ENVIRONMENTAL HYGIENE QUALITY

Regularly scheduled rounds of the environment should be done to monitor housekeeping, regulated medical waste, and compliance to policies, including use of cleaning checklists or other monitoring options. Routine environmental cultures are not recommended. The ASC shall maintain oversight and

ensure the quality of services provided when contracting for cleaning services provided by an outside agency.[2,20,41]

LINEN AND LAUNDRY

ASCs are required to follow the CDC's guidelines for handling and processing laundry.[22] Linen and laundry processes are important in ASCs because anything that touches the surgical patient must be free from contamination and lint, including patient drapes, linens, and surgical scrubs. Clean linen should be packaged, transported, and stored in a manner that will ensure their cleanliness and will protect them from dust and soil. HCP should wear appropriate PPE when handling soiled linens. Handling of linen should be minimized and it should be bagged or otherwise contained at the point of use. ASCs should use leak-resistant bags or containers with labels, color-coding, or other means of communicating that they hold soiled linens.[20,22,42] When services are provided through a contract with an outside resource, the ASC must ensure that these services are provided in a safe and effective manner. ASCs should include the quality assurance monitoring of the laundry services provided in their QAPI programs. Additionally, contracted service employees, including those working in laundry facilities, should meet the requirements of ASCs including education and provision of employee health requirements such as offering Hepatitis B vaccination series. Policies and procedures for proper handling of linen, including bloodborne pathogens protocols, should be established and documented by the laundry facility.[2]

ENVIRONMENTAL CONTROLS

The ASC should have policies and procedures for the ventilation and safe air handling systems (e.g., positive pressure, air changes, humidity, filtration) and water quality control issues (e.g., sterilizer steam, distilled water). Policies for operating rooms (ORs) in the ASC should maintain the same standard as ORs in hospitals (see **68. Surgical Services**). Temperature, humidity, and airflow in ORs must be maintained within acceptable standards to inhibit microbial growth, control odor, promote patient comfort, and reduce the risk of infection. Each operating room should have a separate temperature control.[2] ASC policies should reflect these requirements and records demonstrate that they have maintained acceptable standards.[2] ASCs in which procedures such as endoscopy are performed in procedure rooms that do not meet all of the standard OR requirements may be used. Refer to state regulations for additional information. Acceptable standards can also be referenced in the Association of periOperative Registered Nurses (AORN) 2013 guidelines[20] and Facility Guidelines Institute (FGI) 2010 guidelines.[43]

Additional information on endoscopy procedures may also be found in **55. Endoscopy**.

Procedures should be in place to implement measures to maintain a safe environment during internal or external construction/renovation.[2] ASCs should follow their state licensing requirements for building code requirements and, if required, submission of Infection Control Construction Risk Assessments and risk mitigation plans. Consult the FGI guidelines or local codes for healthcare buildings for further information.[43]

Refer to , for further information.

LIFE SAFETY CODES

ASCs are required to meet the provisions applicable to Ambulatory Healthcare Centers of the 2000 edition of the Life Safety Code of the National Fire Protection Association.[2] However, CMS may waive, if

it is deemed appropriate and will not adversely affect the health and safety of the patients, specific provisions of the Life Safety Code that, if rigidly applied, would result in unreasonable hardship upon an ASC.[2]

Employee Health Program

The healthcare environment presents risks from communicable diseases to ASC employees and other HCP. In order to minimize these risks, the ASC needs to require HCP compliance with established vaccination recommendations, guidelines, and requirements as identified in their policy.[2,44]The employee health program should apply to all employees, faculty, medical staff, temporary workers, trainees, volunteers, students, and vendors, regardless of employer.[2]The ASC should have policies that identify potential healthcare provider work restrictions due to illness with specific communicable diseases.[44]

Facilities should also have procedures to provide medical evaluation, treatment, and counseling for accidental exposures to blood or body fluids as well as communicable diseases such as tuberculosis (TB), pertussis, or varicella zoster. ASCs may contract some or all of these services to occupational health providers or clinics.[2]

HEPATITIS B VACCINE

To comply with OSHA Bloodborne Pathogen Standard,[45]individuals whose jobs involve tasks with potential exposure to bloodborne pathogens (BBP) shall be offered the Hepatitis B vaccine series within 10 working days of beginning their assignment; this vaccine is free of charge to the individual.[45]

Information will be provided on the risk of exposure to occupational Hepatitis B and other BBPs, as it relates to the individual's job assignment. If an individual chooses to decline the vaccine, a declination form will be completed and the individual informed that they may decide to be vaccinated at any time in the future. Postvaccination titers are done 6 to 8 weeks following the completion of the vaccine series. Once seroconversion is established, no further antibody testing is currently recommended. Refer to published recommendations for employees who have negative postvaccination titers to follow.[44,45,46]See Chapters **100**and **101**Occupational Health and Occupational Exposure to Bloodborne Pathogens, for additional information.

TUBERCULOSIS SCREENING

ASC staff, including physicians, should be screened for TB upon hire according to the CDC, OSHA, and state health requirements.[2,47,48]Due to the ambulatory environment and ability to reschedule a surgical procedure, very few patients diagnosed with TB are treated at ASCs. Therefore, most ASCs will be classified as low risk settings for TB exposure.[47]For facilities classified as low risk, all HCP should receive baseline TB screening upon hire, using a two-step tuberculin skin test (TST) or a single blood assay for *Mycobacterium Tuberculosis*(BAMT).[47]Symptom screening should also be performed. Follow state requirements for the time frame that documentation of baseline TB screening following the date of hire, date of executed contract, or date of being granted ASC credentials should be available.[2]For low risk facilities, after baseline testing for infection with *M. tuberculosis*, additional TB screening is not necessary unless an exposure to *M. tuberculosis*occurs.[47]HCP with a baseline positive or newly positive test result for *M. tuberculosis*infection (i.e., TST or BAMT) or documentation of treatment for latent TB

infection (LTBI) or TB disease should receive one chest radiograph result to exclude TB disease (or an interpretable copy within a reasonable time frame, such as 6 months); repeat radiographs are not needed unless symptoms or signs of TB disease develop or unless recommended by a provider.[47] Refer to Chapter **101**, for further information.

ASCs should have OSHA's Blood and Body Fluid Exposure Plans and TB Exposure Control Plans that are each updated annually.[45,48,49]

OTHER

Influenza vaccines should be offered annually to ASC employees, medical staff, students, and volunteers. HCP are strongly encouraged to receive vaccinations to reduce the risk of exposing patients to unrecognized infections. ASCs are encouraged to either require staff to receive vaccine or sign a declination form. Some ASCs require nonvaccinated HCP to wear a barrier mask during the influenza season while in patient care areas.[50]

For the period from October 1, 2014, to March 31, 2015, CMS will require ASCs to report their HCP influenza vaccination rates using NHSN.[13]

Infection Prevention Education

All ASC staff, including physicians, volunteers, and students, should receive orientation and regular update training in basic infection prevention principles including Standard Precautions, specifically hand hygiene, and methods to prevent and control HAI and transmission of communicable diseases.[2]

Employees need to be trained and demonstrate competency when performing infection prevention practices, such as hand hygiene, environmental cleaning, medication administration, and reusable instrument/equipment reprocessing. This should be done prior to the individual performing the work independently.[2]

Emergency Planning and Disaster Management

ASCs should have policies and procedures in place for emergency planning and disaster management that are coordinated with the state and local county health department's community disaster planning efforts.[2] In the event of a mass casualty incident, ASCs may be able to offer additional surgical suites, instruments, equipment, and HCP to assist community disaster relief efforts. In the event of widespread infectious disease outbreaks (e.g., pandemics), ASCs will need to be able to obtain timely information and instructions so that they are in a position to respond and communicate as appropriate with their patients, employees, medical providers, and others. Should the need arise, ASC employee health programs should have a process in place to obtain and administer required vaccines and other medications (e.g., immunoglobulin) as well as have systems in place to track communicable disease exposures to other patients, visitors, or healthcare staff.[2] To prepare for emergencies, ASCs should maintain a contact list of all HCP including home and cell phone numbers and email addresses should a "phone tree" need to be enacted. Additionally, plans should be established for backup provisions in the

event of emergency utility failures (i.e., electrical failures or water loss). A sufficient quantity of waterless hand sanitizers, surgical hand rubs, PPE, and bottled water should be available on site.[2,22]

Future Trends

ASC volume is expected to continue to grow as surgical techniques, analgesics, and technology advances reduce the risk associated with surgical procedures.[1]ASC enrollment in NHSN is expected to surge to over 6,000 in 2014 because of new CMS HCP influenza vaccination reporting requirements.[8]

With CMS's assistance, the CDC is bringing new user support personnel on board to facilitate ASC enrollment in NHSN. The CDC plans to launch a new NHSN Outpatient Procedure Component in mid-2015 that includes several different outcomes: same-day events, SSIs, and early returns to healthcare following outpatient procedures.[8]

HHS, in their updated HAI Action Plan, lists seven key focus areas for HAI prevention in ASCs:[5]

- Engaging stakeholders to facilitate collaboration and to promote a culture of safety.
- Identifying needs and opportunities for HAI reduction through improvement in the process of care within ASCs.
- Disseminating evidence-based guidelines and training for infection control and prevention in ambulatory settings.
- Improving and expanding upon process measures while focusing on specific procedures for application across setting types.
- Expanding current knowledge of surveillance through research to include ASC-specific measures and associated strategies for outcome measurement.
- Expanding the use of financial incentives to encourage the use of beneficial interventions.
- Identify requirements and standards for ASCs to report notifiable diseases and potential outbreaks.

HHS chose specific quality measures for ASCs to monitor in 2013.[8]

Conclusions

ASCs have been facing increased regulatory focus and are now required to have active, dynamic, infection prevention and control programs. These programs need to follow nationally recognized infection prevention guidelines. Infection prevention process measures (e.g., hand hygiene monitors) and outcome measures (e.g., SSI rates) need to be included in their QAPI programs. ASCs are required to have written infection prevention plans that describe the functions and activities of their infection prevention and control program that is overseen by the governing body. Adherence to infection prevention standards and building codes and regulations allow for the safe delivery of procedures in this ambulatory setting.[2]

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Postmortem Care

Author(s): Jeanne Pfeiffer, DNP, MPH, RN, CIC
Infection Control Practitioner

University of Minnesota School of Nursing
Minneapolis, MN

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Abstract

Postmortem care is an evolving specialty that needs to be performed within the framework of preparing for a possible investigation into the cause of death. The initial handling of the deceased is dictated by state and local regulations that determine the cause of death. If an autopsy is required to determine the cause of death, specific protocol to prevent destruction of evidence that might be needed during an investigation will need to be followed carefully. This chapter describes protocol to be followed for patients who expire while under medical care, references procedures that can place staff at risk for occupational exposure, and outlines considerations for handling the decedents from mass casualties.

Key Concepts

- Definition of postmortem care
- Bedside preparation of the deceased patient
- Storage requirements for the deceased
- Criteria for autopsy
- Occupational risks to personnel performing postmortem procedures
- Occupational Safety and Health Administration
- Administrative controls
- Personal protective equipment
- Engineering controls
- Cleaning of environment
- Reprocessing of instruments

- Work practice controls
- Chain of evidence
- Considerations for surge capacity for mass casualties

Background

Bedside postmortem care is, in the broadest sense, the process of preparing the deceased for burial. This process varies from culture to culture and was traditionally carried out by family and close friends supporting the deceased and his or her caregivers. Today in the United States, bedside postmortem care includes bathing and preparing the deceased for visitation from the family, preserving evidence of hospital interventions if an autopsy is required or requested, removing all external devices used during the treatment of the patient if an autopsy is not anticipated, packing all orifices that have the potential to secrete body fluid, and following facility protocol to transport the deceased to the facility morgue.[1]

State statute and/or agency rules, in addition to professional standards, determine the specific steps each hospital follows regarding preparation of the deceased. Postmortem care also presents occupational risks that need to be anticipated and addressed in the administrative plan. The components of the plan must include a hazard assessment, plans to minimize the hazard, use of engineering devices and personal protective equipment to minimize exposure, sorting of waste, record keeping, environmental cleaning procedures, and protocol for reporting accidental exposures. This chapter takes a comprehensive approach to the subject of postmortem care, considering the spectrum of risk presented to those who perform the procedures.

Basic Principles

- Postmortem care: For purposes of this chapter, postmortem care is defined globally as the entire spectrum of care of the body from the time of death through autopsy and transport to a funeral home for embalming or cremation.
- Autopsy: Examination of body, organs, and tissue after death to determine cause of death.
- Occupational risks: Risks to personnel performing postmortem procedures that, by the nature of the work, present hazards such as blood and body fluids, chemicals, weight, radiation, and aerosolization of particles.
- Occupational Safety and Health Administration (OSHA): Federal agency that promulgates and regulates safety standards to protect workers from occupational injury. Organizationally, it is part of the U.S. Department of Labor. Each state is bound by a combination of federal regulations and its individual state occupational health and safety standards.
- Administrative control: Written document that addresses all of the safety aspects of a hazard. OSHA may have specific requirements for identified hazards. OSHA uses a document called a "compliance directive" to delineate the elements of a program that it will regulate.
- Personal protective equipment: OSHA uses this term to describe the equipment recommended and supplied by employers to protect personnel from exposure to specific hazards.
- Engineering controls: OSHA emphasizes evaluating a procedure to determine where new engineering of equipment can remove the hazard.
- Cleaning of environment: All contaminated surfaces must be evaluated and assigned a level of cleaning consistent with the risk.

- Reprocessing of instruments: The process of cleaning, disinfecting, lubricating, maintaining, packaging, and storing between cases.
- Work practice controls: OSHA uses this term to define work practices such as routine procedures to make the workplace safe, including assigned break areas for the consumption of food and beverages, frequency and method of cleaning environmental surfaces, rest periods, dress code, and general rules about maintaining a safe working environment.
- Chain of evidence: This legal terminology is used to describe materials and processes that must be handled in a specified manner to protect evidence from the point of collection to the point of storage in a locked area. This material may be used as evidence in a court of law.
- Considerations for surge capacity for mass casualties: This is the terminology that hospitals use to determine how they can use existing services to accommodate mass casualties from any cause. This includes canceling elective procedures to free up beds and staff to accommodate the unusual number of cases in a given emergency.
- Mass fatality incident: An incident where more deaths occur than can be adequately managed by local resources.
- Disaster Mortuary Operational Response Team: A response team of trained specialists in victim identification and mortuary services. The teams operate within the National Disaster Medical System and are part of the federal response to disasters under Federal Emergency Management Agency's Emergency Support Function #8: Health and Medical Care to provide victim identification and mortuary services.

Specifics Of Postmortem Care

RISKS

Preparing the decedent for the morgue always involves the handling of blood, body fluids, and biological agents and may also involve exposure to life-threatening biologicals, chemicals, radiation, or electrical current.

INTERVENTIONS

1. Postmortem care begins immediately after pronouncement of death through cleansing of the body before removal for final disposition.[1] Standard Precautions at a minimum are required throughout this process.[2,3,4,5,6]
2. Invasive lines and devices (intravenous catheters, endotracheal tubes, nasogastric tubes, urinary catheters, electrical impulse devices) are removed and disposed of according to state and local regulations unless the body is scheduled for autopsy, in which case invasive therapy devices are left in the body.[5]
3. Wounds and natural openings may be packed with absorbent material and bandaged to contain body fluids.[5]
4. State health codes dictate refrigerator storage temperatures in the morgue; local disaster plans should address contingent expansion of morgue facilities.[5,7]
5. State health codes may dictate shroud specifications (e.g., design, thickness of plastic) for transport of the body from morgue to a funeral home.[5]

AUTOPSY

The College of American Pathologists has developed a list of conditions in which it may be desirable to perform an autopsy[8]:

1. Deaths in which autopsy may help to explain unknown and unanticipated medical complications to the attending physician.
2. All deaths in which the cause of death or a major diagnosis is not known with reasonable certainty on clinical grounds.
3. Cases in which an autopsy may help to allay concerns of, and provide reassurance to, the family and/or the public regarding the death.
4. Unexpected or unexplained deaths occurring during or following any dental, medical, or surgical diagnostic procedures and/or therapies.
5. Deaths of patients who have participated in clinical trials (protocols) approved by institutional review boards.
6. Unexpected or unexplained deaths that are apparently natural and not subject to a forensic medical jurisdiction.
7. Natural deaths that are subject to, but waived by, a forensic medical jurisdiction, such as persons dead on arrival at hospitals, deaths occurring in hospitals within 24 hours of admission, and deaths in which the patient sustained or apparently sustained an injury while hospitalized.
8. Deaths resulting from high-risk infections and contagious diseases.
9. All obstetric deaths.
10. All perinatal and pediatric deaths.
11. Deaths in which it is believed that an autopsy would disclose a suspected illness that may have a bearing on survivors or recipients of transplant organs.
12. Deaths known to or suspected to have resulted from environmental or occupational hazards.

RISKS

There is the potential for exposure to hazardous radioactive materials, chemicals such as formaldehyde and glutaraldehyde, or poisons such as cyanide.[9,10] There is potential for electrical shock from an individual arriving with an implanted cardioverter-defibrillator that has not been deactivated.[11]

Occupational transmission of disease associated with autopsy has been described as a subset of all laboratory-acquired infections.[4] In one series, infections resulting from autopsy represented 1.9 percent of all laboratory infections.[12] Accidents, including exposure to aerosol, spill/spatter, and punctures with sharp objects, have resulted in bloodborne diseases and tuberculosis (TB).[6,13,14,15,16,17,18,19,20] Creutzfeldt-Jakob disease (CJD) transmission associated with autopsy has been documented and is addressed in specific precautions for known or suspected cases.[18,19,21] Ten percent formalin (3.7 percent formaldehyde), in at least 10 times the volume of tissue properly sectioned and adequately permeated, will inactivate all important infectious agents except the agent of CJD, kuru, and *Mycobacterium tuberculosis*.[5,19,21,22]

INTERVENTIONS

1. Perform all procedures with minimal distractions, adequate assistance, and alert staff.[5,22,23]

2. Operate as though the entire autopsy suite and its contents is a biohazardous area.[5,22,24,25]
3. Precautions include standard use of personal protective equipment, engineering devices to minimize exposure, and work practices that delineate which tasks or conditions of employment require protective equipment and engineering devices, where the employee may safely consume food and beverages, and how the employee would clean up a blood spill and report an exposure. These precautions are regulated by the U.S. Occupational Safety and Health Administration (OSHA).[3,5,6,16,23]
4. All persons performing or assisting in postmortem procedures should wear double layers of disposable gloves, protective eyewear and face wear, respiratory protection, fluid-resistant gowns or jumpsuits, waterproof aprons, and protective shoe covers and caps. Evidence suggests that metal and mesh gloves worn underneath surgical gloves may prevent against injury from scalpels and sharp objects other than needles.[2,3,5,6,22,23,26,27,28]
5. OSHA determines performance of an autopsy on a known or suspected case of TB to be a high-hazard procedure requiring personnel to use approved respiratory protection.[29,30]In areas where

   TB is prevalent and the health history is unknown, respiratory protection is prudent, especially for medical examiner's cases.[23,24,31]
6. Instruments and surfaces contaminated during postmortem procedures should be reprocessed according to standard procedures to remove all vegetative organisms.[5,6]Enzymatic cleaners,

   intermediate-level disinfectants, and instrument washer-sterilizers may all be included in the processing. Autopsy tables must be flushed of gross material with water followed by disinfectant and detergent scrub of all surfaces and rinsing.[5,6,22,32,33]
7. Safer engineering designs are available for cutting and aspirating, for ventilation of procedure rooms, and for autopsy equipment, including protective guards, vacuum attachments fitted to bone saws to prevent dispersion of bone dust, and drains or disposal units to facilitate evacuation and disposal of solid wastes produced during autopsy (e.g., drain or disposal unit).[5,6,22,32,34,35,36]
8. Autopsy rooms should be at negative pressure with respect to adjacent areas, with room air exhausted directly outside. The American Society of Healthcare Engineers recommends 12 air changes per hour.[22,23]
9. In-duct, high-efficiency particulate air filters used prior to recirculation or ultraviolet germicidal irradiation may supplement recommended ventilation.[23,30]
10. Sharps hazards are minimized for prosectors (those performing postmortem tissue dissection) by the following: using gloves made with "cut resistant fabric" under the outer glove, limiting scalpel use by blunt dissection with blunt-tipped scissors, having careful tabletop instrument control, minimizing the presence of sharp instruments on the autopsy field to one scalpel, taping or covering with towels cut bone and jagged rib edges, limiting blind evisceration, sawing skull with head and saw enclosed in plastic bag or box taped at the portals to avoid aerosolization of dust, announcing in advance any repositioning of sharp devices, and avoiding hand holding of bottles when injecting body fluids or passing of devices during the procedure.[5,22,30]
11. Work practice controls include treating all specimens as infectious, retaining all tissues on the autopsy table until fixed unless transported on a tray or in a container, cutting frozen sections only on fixed tissue, and appointing a designated employee/circulator who will facilitate adherence to infection prevention precautions by preparing the room, assisting with photography, handling communications, or having personnel gather all the necessary supplies before the procedure begins.[5,6]

12. At the completion of the autopsy, incisions are sutured with needle and forceps, the body is washed with detergent followed by 1:10 solution of 5.25 percent sodium hypochlorite, and is enclosed in a leakproof body bag.[5]
13. Special tissue precautions: CJD tissue fixatives should be prepared by soaking small blocks of tissue in 95 to 100 percent formic acid for 1 hour, followed by soaking in fresh 4 percent formaldehyde for at least 48 hours. When *M. tuberculosis*is known or suspected, tissue fixatives should be prepared with 10 percent formalin in 50 percent ethyl alcohol (one part 3.7 percent formaldehyde plus nine parts 10 percent ethanol in saline).[5]
14. Instruments used on suspected CJD patients should be steam autoclaved for 1 hour at 132°C (270°F) or immersed in 1 N sodium hydroxide for 1 hour at room temperature.[19,22]
15. Surveillance of autopsy reports may suggest information on previously undiagnosed infections, though some investigators question the utility of reviewing necropsy reports. One report reviewed 15 months of reports, or 155 cases, finding an 8 percent discrepancy between clinical observation and autopsy findings, with none of these having an infection prevention impact on patients or employees.[37]Screening of these cases by the pathology department (e.g., only reports indicating TB or communicable disease) may increase the efficiency of this process.[24,38]

Autopsy Tissue and Chain of Evidence

RISKS

There is potential for exposure to chemicals and infectious agents from clothing and personal effects retained by the medical examiner for evidence.

INTERVENTIONS

All contaminated items retained for evidence should be air dried at room temperature, wrapped for storage, placed in a bag labeled with a biohazard sticker, and locked in a secured area. Tissues retained for evidence must be fixed in standard solutions, photographed per protocol, and stored in a secure area. Exteriors of containers are labeled with biohazard stickers and wiped with disinfectant before being placed in storage.[5,6]Surfaces that have been contaminated with material from one decedent should be cleaned and disinfected before using the surface for the examination of materials from another decedent to protect the chain of evidence.[32,33]

Embalming and Restoration

RISKS

The risk of occupational chemical and bloodborne pathogen exposure for embalmers is not well documented. Limited investigations indicate that sharps exposures are common, and though Standard Precautions are maintained for individuals known to be infected, adherence to these standards is not consistent for all cases.[22,39,40]Unrecognized cases of bloodborne disease pose significant risk to mortuary workers because bloodborne pathogens such as human immunodeficiency virus-1 survive in cadavers for up to 6 days after death.[5,6,14, 15]Embalming fluid, which is required to contain

formaldehyde by all states, is intended to disinfect the body in preparation for burial and creates a potential chemical hazard for embalmers. The practice of increasing the concentration of formaldehyde for "infected cases" complicates this hazard.[22,41]

INTERVENTIONS

The funeral home industry and professional associations have made significant efforts to educate their members about Universal/Standard Precautions and effective methods to address occupational risks. Compliance with the OSHA standard is often voluntary due to the limited numbers of workers employed by small proprietary businesses.

Conclusions

Postmortem care includes the basic preparation of the body for burial. The deceased is released from a facility to a funeral home selected by the family. The staff at the funeral home assists the family with public notification of the death, disposition of the body, completion of the death certificate, and religious ceremonies. This chapter describes the spectrum of conditions that may put others at risk for occupational hazard during this process.

Future Trends

Safety standards must be uniform across the healthcare industry. Most medical examiner, coroner, and hospital autopsy facilities in the United States are not constructed to enhance biosafety.[42]The number of autopsies being performed in the United States is decreasing, whereas the hazard risks for cases requiring autopsy are increasing. For example, some populations at higher risk for sudden death that prompts an autopsy are also at higher risk for certain infectious diseases (i.e., 79 percent of injection drug users are infected with Hepatitis C virus). Forensic pathologists are exposed to needles, broken glass, bone shards, and fragmented projectiles, as well as large amounts of blood and body tissue, on a daily basis.[22,43]

Most autopsy rooms are not designed to meet the engineering requirements and current Facilities Guideline Institute recommendations of the AHSE. Most operate at biosafety level 2 at best, though all should be at biosafety level 3. Funding is needed to remodel existing or build new regional facilities.[22]In the event of mass casualties from any cause, the ability of hospitals and medical examiners to appropriately maintain all human remains is questionable. Processes must be in place in each community to plan, prepare, train, and mobilize other resources, such as funeral homes, to assist during emergencies and establish temporary morgues.[25]These temporary sites will require control of ventilation, temperature, biohazards, water supply, lighting, waste, and pests. They will also need to accommodate family viewing areas and provide adequate rest areas for staff. These off-site facilities will need to be included in a community incident command system.

During an emergency that requires opening of such a temporary facility, an off-site morgue unit leader will need to be in communication with an incident command center and organizations like the American Red Cross, whose role is to track patients and notify families of their status.

These areas will have to plan for additional staffing, security, and psychological support. An off-site morgue unit leader will be faced with moral, cultural, and religious issues. They may also be subject to significant changes in procedures or chains of command, because during disasters occurring in the United States, the president and the state governors are given extraordinary powers to protect people and property.

In the United States, Disaster Mortuary Operational Response Teams (DMORTs) are utilized during mass casualty incidents when local resources/capabilities have been exceeded. In these situations, the local medical examiner would request additional resources/assets through the local emergency management process that is already in place. DMORTs also have extensive experience working with the National Transportation Board following airline and rail incidents.[44] Team members represent a variety of areas of expertise including fingerprint technicians, dental assistants, coroners, medical examiners, medical records technicians, pathologists, forensic anthropologists, radiologists, forensic odonologists, funeral directors, mental health professionals, and support staff. There are three federal Deployable Portable Morgue Units that are able to deploy, fully equipped, to support DMORT functions on the scene of a disaster when additional morgue facilities are needed. DMORTs can provide assistance with temporary morgue facilities, victim identification, forensic dental pathology, forensic anthropology methods, and processing and disposition of remains.[44]

Lessons can be learned from the experiences of the U.S. military in planning for and handling mass casualties in war situations in a manner that protects soldiers, citizens, the deceased, and national security.[45] For example, the communications officer at the off-site facility will need to establish briefing sessions with the community incident command center. Each event will require an assessment of exposure risk to biological, chemical, and radioactive hazards. Eventually, orders will be given to release the remains to the families for a usual burial or will be retained and designated for cremation or incineration.

The National Association of Medical Examiners (NAME) has developed guidelines for preparing a mass fatality plan, which are available online through the NAME website (**www.thename.org/library**).[46]

International Perspective

Burial practices are driven by the cultural values and historic practices of a group. When these burial practices are associated with life-threatening disease transmission and/or death, the World Health Organization will investigate and recommend control measures to prevent further transmission. Both kuru prion and Ebola virus have been associated with transmission of disease to family members during rituals associated with preparing the body for final disposition.[47,48,49] Maujean and colleagues in France and Schwark and colleagues in Germany performed environmental sampling methods and identified unacceptable levels of fecal flora and DNA from previous decedents after environmental surfaces had been disinfected. Both of these teams identified problems with contamination in relation to investigation of medical-legal cases and concluded that their practices needed to be reevaluated.[32,33] Another German team led by Ramsthaler implemented Centers for Disease Control and Prevention recommendations for autopsy practices in light of the H1N1 pandemic and the anticipated need to perform more of these high-risk cases.[50] Aydin and colleagues conducted a survey of Turkey's forensic medicine specialists to identify their frequency of using personal protective equipment during autopsy practices; investigators

discovered opportunities for improvement nationwide to protect forensic workers who are at a higher risk for acquiring infectious diseases during these procedures.[51]

Interpol, a worldwide police organization with 181 member countries, has published a model set of procedures for setting up victim identification units and temporary morgues during world disasters of any kind. This resource is complete with job descriptions for staffing such units.[45]

Supplemental Resources

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202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Rehabilitation Services

Author(s): Amelia Bumsted, DNP, RN, CRRN, CIC, FAPIC
Manager, Infection Control Section

Edward Hines Jr. VA Hospital
Hines, IL

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Abstract

The rehabilitation setting is challenged with treating the entire patient: mind, body, and spirit. The conceptual framework of holistic nursing, a common practice model in the rehabilitation setting, views environment as healing.[1] This presents a challenge when the infection preventionist is faced with a patient with a multidrug-resistant organism that requires Contact Precautions, limiting the patient's movement in the environment. Rehabilitation facilities must evaluate the numerous factors that influence transmission risks and their unique settings to develop infection prevention policies and procedures that apply to the types of patients they treat and the services they provide. Transmission-based Precautions are based on the current knowledge of disease transmission and therefore need to be applied in the rehabilitation setting with the same principles. Team members may need to wear gowns, masks, or gloves in the hallways or in gym areas when working with a patient with an MDRO. Family members who assist with care need to be educated on MDROs and good hand hygiene practices while at the facility and in preparation for discharge. Equipment used to provide rehabilitative services to the patient may present increased risk of infection. Disinfection of the environment and equipment, along with frequent hand hygiene, are important infection prevention strategies to interrupt the chain of transmission of infectious pathogens in inpatient rehabilitation facilities. In the rehabilitation population as a whole, there are many specialty populations with unique needs and characteristics that affect their risk for and response to infection. In order to perform meaningful surveillance in these specialty populations, a thorough understanding of these unique characteristics and how they relate to traditional methods and surveillance definitions is required.

Key Concepts

- The goal of rehabilitation is to mitigate the disease process, restore function, reestablish self-care, and to prepare the patient for reentry and reintegration into community.[2,3]

- Rehabilitation is a high-touch, highly interactive level of care.
- The location of the rehabilitation unit/venue for services may determine the approach to infection prevention.
- For freestanding facilities, there are usually a number of referring hospitals—increasing the pool of potential endemic organisms and multidrug-resistant organisms from the referring community.
- Patients interact with many healthcare personnel throughout the day. Additionally, healthcare personnel, particularly within allied health, interact with many different patients a day—significantly increasing the chances for cross-contamination.
- There are currently no official infection prevention standards specifically for rehabilitation. Guidance for the development for infection prevention and control programs in rehabilitation can be adapted from authoritative guidelines for long-term care facilities.[4,5]
- Comorbidities that contribute to lower scores on measures of activities of daily living function also are predictive of a higher risk for healthcare-associated infections, compounding the importance of a strong infection prevention and control program (including surveillance) in rehabilitation units.[6]
- An important aspect of rehabilitation is the patient-centered care framework.[3]The interdisciplinary plan of care for patients in rehabilitation is very individualized.

Background

Postacute care (PAC) is a term to describe the spectrum of the healthcare journey that begins upon discharge from acute care and follows patients requiring further medical care and interventions. The scope of the problem, patient and family resources, and insurance coverage all play into the determination of patient disposition after acute care hospitalization.

Although similar to the acute hospital in terms of patients' needs of nursing and medical care, facilities in the PAC setting have unique features as far as the populations they serve, services they offer, payment systems, qualifications for appropriateness of admission, and focus of care.[3,7]Those patients stabilized but continuing to need intense medical intervention or technology for an extended length of stay (but with the anticipation that they will improve) are typically discharged to a long-term acute care hospital (LTACH). Some of these patients may be able to be serviced in the home with specialized home health services.

Patients who require continued assistance with activities of daily living or medical management of their care plans can be serviced in a long-term care (LTC) facility, sometimes referred to as a skilled nursing facility (SNF) or nursing home. These facilities have a different focus for the care they provide, delivering care in a residential setting. Assisted-living facilities are yet another option in the PAC setting for patients requiring less supervision or intervention.

Following a debilitating illness, injury, stroke, or other incident precipitating a decline in functional independence, a patient may be referred for acute rehabilitation services.[8]Rehabilitation services can be delivered in a variety of settings in addition to the ones mentioned above: inpatient units within an acute care hospital, freestanding acute inpatient rehabilitation facilities (IRFs), and outpatient rehabilitation.[7]

Rehabilitation services can also be provided in the home through a home healthcare provider or in a community setting. Some SNFs provide lower intensity rehabilitation in what is called a *subacute*setting

for patients requiring skilled nursing and medical care, but who are not able to tolerate the standard 3 hours per day of therapy.[3,7] Although the services may be similar, differences in venue determine what regulatory agencies preside over the practice standards related to infection prevention. For example, state departments of health govern SNFs whereas IRFs may submit to the Commission on Accreditation of Rehabilitation Facilities (CARF) and The Joint Commission (TJC) standards for infection prevention.

This chapter addresses the specifics for the infection preventionist (IP) responsible for the infection prevention and control program within an acute care facility or for a freestanding IRF.

Basic Principles

HEALTH DISPARITIES IN PERSONS WITH DISABILITIES

The concept of disability as it relates to health is important to understand when planning care for patients in rehabilitation, including infection prevention strategies. The World Health Organization (WHO) discusses three dimensions of disability involving structural or functional changes to the body (blindness, amputation); limitations in relation to activities (solving problems, walking); and being restricted from normal participation in activities of daily living (driving, cooking) when this disability occurs as a result of disease or health-related condition.[9] As a result, the person experiences limitations that are barriers (stairs, not being able to read computer screens, unable to transport self to clinics) within their social and communal environment, although the barriers themselves are not a disease process.[10,11] U.S. studies show that among adults with disabilities, approximately 39 percent report fair to poor health (on a five-point scale) in contrast with less than 9 percent amongst their counterparts without disabilities.[11]

The Centers for Disease Control and Prevention (CDC) recommends to incorporate interventions that address common barriers, create a barrier-free environment if possible, and to use condition-specific focus where necessary.[11]

Patient-centered, Holistic Framework for Rehabilitation

The above information is important to keep in mind as you assess the infection prevention needs of the populations in your facilities. The rehabilitation setting is challenged with treating the entire patient: mind, body, and spirit. A tenet of rehabilitation is patient-centered care with the goals of restoration of function and reestablishing self-care.[2,3] Whereas LTC seeks to create a homelike environment to facilitate assimilation into the institutional setting, rehabilitation seeks (where possible) reintegration into the community.[3,12]

The conceptual framework of holistic nursing, a common practice model in the rehabilitation setting, views environment as healing.[1] This presents a challenge when the IP is faced with a patient with a multidrug-resistant organism (MDRO) that requires Contact Precautions, thereby limiting the patient's movement in the environment. The practice of rehabilitation is not merely a repetition of a series of muscle-strengthening exercises, but rather developing strengths within the whole person that will increase their resiliency in the face of the challenges of their condition.[12] Therefore, therapists utilize various settings within the facility and perhaps on the grounds or in the surrounding community to conduct sessions with patients. Group sessions are used not only to maximize scheduling, but also to aid in the reintegration process. The IP should be part of the interdisciplinary team evaluating the plan

of care for individual patients to maximize their therapeutic sessions while maintaining a safe environment for the patients, staff, and visitors.[12,13]

NEW ROLE FOR INFECTION PREVENTION WITHIN REHABILITATION

Although rehabilitation facilities may have had infection prevention and control programs in place, the introduction of mandatory reporting to the National Healthcare Safety Network (NHSN) as part of fulfilling quality reporting requirements with Centers for Medicare & Medicaid Services (CMS) has elevated the importance of the IP's role in not only compliance, but reimbursement. As of October 1, 2012, IRFs are required to report catheter-associated urinary tract infections (CAUTIs) or face penalties for noncompliance.[14] At this time, there are no established infection prevention-related performance requirements for IRFs, but these will undoubtedly be phased into the program. As performance equates dollars, administration at IRFs will be looking to infection prevention for guidance to ensure maximum reimbursement. It is definitely an opportunity for the IP to develop leadership competencies and performance improvement and implementation of science competencies as listed in the APIC white paper on current and future competency in infection prevention.[15]

LEVELS OF PREVENTION FRAMEWORK

In the public health model, the levels of primary, secondary, and tertiary prevention address the goals of interventions: preventing the disease, identifying the disease process before its full clinical expression, providing early treatment, or slowing/blocking the disease process to reduce impairments and restore function and quality of life.[16] Rehabilitation is an example of tertiary prevention that plays an important role in developing a context for infection prevention activities.

Patients in rehabilitation may have either temporary or permanent disabilities that, by their nature, serve as risk factors for developing further complications and secondary health conditions such as infection. Immunization, therefore, should be appropriately offered to the populations at risk within the facility. Examining the effect of influenza on functional decline, a 2012 study determined that influenza has a great cost to the elderly patient in terms of activities of daily living score loss (>4 points) associated with increased mortality (p<.001), increase in new or worsening pressure ulcers, and additional infections (p< .001).[17] In a prospective cohort study on a geriatric rehabilitation unit, 97 out of 252 patients included in the study experienced healthcare-associated infections (HAIs; incidence 5.6 HAIs/1,000 patient bed days) with a comorbidity index higher in patients with HAIs compared to those without HAIs.[6]

Patients may arrive having just recovered from an infective process that was either community- or hospital-associated.[8] In a study of nursing home residents, researchers highlight the reciprocal relationship between decline in functional status and infection as both a risk factor and an outcome.[18] Admission for suspected sepsis is associated with a considerable risk of requiring assisted living or rehabilitation services upon discharge.[8] An infection and subsequent revision of a total joint arthroplasty can significantly increase the length of stay and decrease functional outcomes, even after infection clearance, in a rehabilitation patient.[19]

INFECTION PREVENTION STRATEGIES

Infection prevention and patient safety efforts in rehabilitation facilities are similar to those in acute care facilities. In addition, rehabilitation healthcare personnel (HCP) must develop and implement plans of

action for prevention of HAIs and patient safety unique to rehabilitation. Standard Precautions apply and should be implemented across the continuum of care for all rehabilitation settings. Major concerns for rehabilitation HCP include hand hygiene, cleaning and sterilization of endoscopic and patient equipment, advanced wound care, pressure ulcer prevention and treatment, Transmission-based Precautions, contaminated medications, contaminated environmental surfaces, food safety, proper treatment and handling of linens, and needlestick/sharp injuries.

Rehabilitation facilities must evaluate the numerous factors that influence transmission risks and their unique settings to develop infection prevention policies and procedures that apply to the types of patients they treat and the services they provide. These factors include population characteristics (i.e., increased susceptibility to infection, prevalence of indwelling devices); intensity of care; frequency of interaction between patients and HCP; and length of stay. Facilities also need to assess the data regarding institutional experience with endemic organisms, trends in the community for HAIs, and emerging infectious disease threats when developing infection prevention guidelines.[5,20]

Prevention Begins Before Admission

The process for admission to a rehabilitation facility involves the assessment of the patient's condition and potential for rehabilitation by a physical medicine and rehabilitation (PM&R) physician or physiatrist.[7,13,21] An admission or clinical liaison usually performs the initial referral process and coordinates medical history review and communicates medical necessities to the admission department for placement within the rehabilitation facility. The IP should coordinate with the admissions department on what data is necessary to be obtained by the clinical liaison in order to provide a safe transition of care from an infection prevention standpoint. Common data necessary to the IP are:

- Has the patient recently undergone surgery? If so, name of surgery, facility, and date of surgery.
- Plans for follow up with surgeon and specific directions for site care (wound care, suture/staple removal, etc.).
- Dates of previous hospitalizations, residence in assisted living or skilled nursing facility, locations, and current length of stay.
- Has the patient been treated during these stays with multiple antibiotics? Is the current antibiotic to be continued? Stop dates?
- Does the patient have a current active infection, recently treated infection, or current/history of any MDRO infection or colonization?
- Dates and location of positive cultures—copies of actual cultures to be sent, if available. Dates of negative cultures are also helpful.
- Has the patient and family been educated regarding specific MDROs, isolation, and necessary precautions?
- Does the patient have nonintact skin, rash or lesions, open wounds, stasis ulcers, open burn wounds, or indwelling devices?
- Dates of insertion and removal of any indwelling devices.
- Does the patient have bowel or bladder incontinence?
- Is the patient currently experiencing any loose stools/diarrhea, fever, vomiting, abdominal cramping?
- Does the patient have any drains, ostomies, or implanted devices?
- Does the patient have any excretions or secretions that cannot be contained?

- Is the patient willing or cognitively able to cooperate in strategies to contain his or her own body secretions?
- Has the patient been intubated? Do they have a tracheostomy? Do they have swallowing strategies or aspiration risks?
- Dates of vaccinations (influenza, pneumococcal, shingles), if known.

POPULATION-BASED RISK FACTORS

Patient populations in rehabilitation may differ from facility to facility based on specializations, location, technology available, referral sources, and payor sources. The Prospective Payment System (PPS) for medical rehabilitation mandates that in order to receive reimbursement from the CMS, at least 60 percent of diagnoses must come from 13 core categories which include stroke, spinal cord injury, congenital deformity, amputation, major multiple trauma, fracture of the femur (hip fracture), brain injury, multiple sclerosis, motor neuron diseases, polyneuropathy, muscular dystrophy, Parkinson disease, and burns.[21] Rehabilitation patients frequently present with cognitive deficits and functional impairment issues (e.g., bladder and bowel incontinence) that may make patient compliance with hand hygiene challenging.[4] Also commonly noted in rehabilitation patients is impaired cough or gag reflex and swallowing disorders.[4] Rehabilitation patients may have other issues that predispose them to and increase risk of infection, such as recent surgery, major organ failure or tissue replacement, age, impaired respiratory function, or implanted hardware. Some patients who come into the rehabilitation setting are not alert and oriented and are unable to verbalize symptoms of infection. Some patients have neurological impairments that keep them from being able to recognize symptoms of infection.

STANDARD PRECAUTIONS

Standard Precautions apply and should be implemented across the continuum of care for all rehabilitation settings.

TRANSMISSION-BASED PRECAUTIONS

Transmission of MDROs is an issue of great concern for all healthcare facilities. Transmission-based Precautions are based on the current knowledge of disease transmission and therefore need to be applied in the rehabilitation setting with the same principles. Infected or colonized patients serve as a source, but it takes a portal of exit, a susceptible host (which would describe most rehabilitation patients), a portal of entry, as well as a mechanism of transmission in order to complete the chain of infection. Acknowledging that the HCP's hands are the most likely means of transmission sets the priority for Transmission-based Precautions—hand hygiene and proper use of personal protective equipment (PPE) for the appropriate task will significantly interrupt the transmission potential in the rehabilitation environment. Team members may need to wear gowns, masks, or gloves in the hallways or in gym areas when working with a patient with MDRO. Family members who assist with care need to be educated on MDRO and good hand hygiene practices while at the facility and in preparation for discharge. To further examine the risk of transmission, the IP must examine the:

- Nature of the microorganism with which the patient is infected and/or colonized, and the portals of exit for the microorganism from the patient.
- How much direct care or assistance the patient needs, and the amount of contact with body fluids that could occur during this care.

- Patient's ability to control secretions or excretions, or the ability of barriers, collection devices, or dressings to contain drainage.
- Level of activity and mobility of the patient and their cognitive ability to comprehend instructions or comply with hygiene regimens.
- Level of environmental controls and supervision available to attend to disinfection.

Encouraging patient mobility, direction of care, and physical independence are important in the rehabilitation setting and may conflict with traditional application of Transmission-based Precautions. If a patient is known to be infected or colonized with an MDRO, the IP can help guide the interdisciplinary team in reviewing the case and making decisions about care, point of service, and restrictions that will be placed on the patient. Each situation should be reviewed with recommendations individualized for the needs of each patient. Appropriate antimicrobial stewardship that includes optimal selection, dose, and duration of treatment as well as control of antibiotic use is important in the healthcare setting. The pharmacist can help with the monitoring of antibiotic usage in the rehabilitation setting.

With proper planning, patients with MDRO can be involved in group recreational/learning activities or leave the facility for community integration. When a patient with an MDRO needs to leave their room for social or therapeutic reasons, part of the environmental controls may include providing the patient with an escort or transport from place to place that can ensure prompt disinfection of surfaces in common areas if inadvertently contaminated. Family can be included in this plan, if appropriate.

In considering patient rights as they relate to infection prevention, the ethical principles of justice and beneficence must be balanced.[22] Preventing avoidable exposure while promoting personal dignity for the populations served is the heart of infection prevention in the rehabilitation setting. Qualitative studies have been conducted examining the experience of the person in precautions which identified the common themes of disconnection, stigmatization, shunning, and fear.[23,24,25] Before universally restricting patients, the IP should perform a facility risk assessment and identify areas of priority where workflow controls can reduce the patient burden of infection prevention measures. A study of strict isolation for methicillin-resistant *Staphylococcus aureus*(MRSA) in a rehabilitation study resulted in some very helpful ideas for combatting common pitfalls in the rehabilitation setting.[25] One recommendation was to provide educational classes about MRSA for all families, visitors, and patients—not just those who are MRSA positive. Another suggestion was to discuss with the patient whether or not they want to be the ones to inform their family, or if they prefer to have a staff member provide this information while educating them as well.[18,26] One final action item that resulted from this study was considering utilizing more neutral PPE, such as a blue gown that matches uniforms rather than yellow that signifies caution. Some simple modifications, taking the patient's perspective of the experience, facilitate that ethical balance of infection prevention.[22]

Outbreaks, Extensively Drug-resistant Organisms, and Carbapenem-resistant Enterobacteriaceae

As much as rehabilitation seeks to incorporate inclusion into the philosophy of care, some circumstances require adherence to a more stringent, traditional acute care style of precautions. In the circumstances of an outbreak, the IP must utilize all principles of outbreak control, including limiting admissions, closing units, furloughing ill staff, and isolating infected patients (see **12. Outbreak Investigations**). Another developing threat to the health and welfare of all patients across all settings is the emergence of extensively drug-resistant organisms (XDROs), such as carbapenem-resistant Enterobacteriaceae (CRE). Identified by the CDC as a "serious threat to public health," CRE must not be taken lightly in any

setting.[26] Due to the "person" factors of patients from multiple referring partners gathered in one facility after extended hospitalization with likely exposure to an intensive care unit (ICU) and antibiotics, and the "environmental" factors of a setting that is encouraging mobilization of these vulnerable patients requiring high-touch care, the rehabilitation setting could be a catastrophic contributor to the CRE crisis without careful planning.[26] The IP should stay current with the latest CDC and public health authorities' recommendations for control of this organism in their setting. Consultation with administration should be undertaken if there is concern about the ability of the staff to adhere to the requirements of proper isolation of this organism within the scope of that particular rehabilitation program. As there are no current guidelines for the discontinuation of precautions for CRE at this time,[26] policies must be reviewed to ensure safe care for the patients and staff in the presence of these infections. The well-informed IP can guide staff, patients, and families through the difficult task of learning what colonization or infection with CRE means, and develop innovative ways to adapt to even this challenge—in the true spirit of rehabilitation services.

HAND HYGIENE

In the rehabilitation setting, patient movement throughout the facility is the norm rather than the exception. Facilitating this movement is often a team of transporters or volunteers that can come in contact with a significant number of patients in a day, depending on the size and structure of the facility. In a novel exploration of super-spreading events, a team from the University of Iowa's computation epidemiology department demonstrated how a lapse in hand hygiene in such highly connected HCP could dramatically impact diffusion of pathogens throughout a facility.[27] It is important for the IP to take this into consideration in risk assessment, policy development, training of staff and volunteers, placement of hand hygiene products, and outbreak investigation.

The abundance of hand hygiene opportunities during therapy sessions presents another infection prevention challenge. In a 2013 study on hand hygiene of 171 therapists during neuromotor rehabilitation, the authors found compliance rates of 36.5 percent before patient contact, 25.4 percent after patient contact, and 22.5 percent after contact with the patient's surroundings.[28] Additional studies have examined the importance of the compliance with hand hygiene in the context of a series of activities rather than the isolated in/out of the room events, and the positive impact that contextual, multifaceted education and training can have on this particular aspect of infection prevention.[29]

Hand hygiene monitoring can be challenging in the rehabilitation setting, particularly in the therapy gyms and in group settings. Whether a facility chooses to follow the hand hygiene guidelines from the CDC[20] or WHO,[30] education for the allied health staff regarding the indications for hand hygiene and practical applications to the environment and context of their therapy modalities is important. The WHO has a separate guide for hand hygiene in outpatient, home-based, and long-term care facilities[31] that contains guidance specifically for scenarios involving physiotherapy sessions. The pictures, charts, and descriptions in the WHO guide may make the moments for hand hygiene opportunities clearer for rehabilitation staff because they resemble more closely their patient populations (up and ambulating with an assistive device), as opposed to the classic "My Five Moments for Hand Hygiene" graphic[30] depicting a patient in a hospital bed with an intravenous line and an indwelling catheter tethered to the bed. (See **27. Hand Hygiene**.)

PERSONAL PROTECTIVE EQUIPMENT

Gloves, gowns, masks, and protective eyewear/face-shields should be available as part of the rehabilitation HCP's PPE and used when there is a risk of exposure to blood and other potentially infectious body fluids. In addition, guidelines for the use of PPE with Transmission-based Precautions should be included in facility policies and reflect evidence-based practices appropriate for the setting.[4,5,20,30,31,32,33] As there are no specific guidelines for rehabilitation, adaptations to setting-specific guidelines for acute, long-term care, and outpatient settings as appropriate can knit together a comprehensive infection prevention plan for the rehabilitation setting. A carefully executed risk-assessment should highlight the priority areas to address and help direct toward the appropriate guidelines.

See **28. Standard Precautions**, and **29. Isolation Precautions (Transmission-based Precautions)**).

DISINFECTION AND STERILIZATION PROTOCOLS FOR THERAPY AND PATIENT CARE

Equipment used to provide rehabilitative services to the patient may present increased risk of infection. Examples of equipment include: canes, walkers, and other assistive devices; orthotics and prosthetics; transfer equipment such as mechanical lifts or stands with accompanying slings and belts; specialty beds; electric and manual wheelchairs; weights, medicine balls, and other small gym equipment; treadmills, stationary bicycles, stair climbers, etc.; ultrasonic or hydrotherapy devices; therapy pools and whirlpools; TENS units, EMG, and biofeedback devices; driving simulators or modified vehicles; dialysis machines; and ventilators and respiratory therapy supplies.

Disinfection of the environment and equipment, along with frequent hand hygiene, are important infection prevention strategies to interrupt the chain of transmission of infectious pathogens in inpatient rehabilitation facilities. HCP need to understand and adhere to department-specific guidelines for cleaning and disinfecting the equipment following each patient use; these guidelines should include methods for documenting and validating that equipment cleaning and disinfection have been done.[34] The facility's policies should identify equipment that is appropriate for sharing versus equipment that should be dedicated to a specific patient. If equipment is shared, it must be cleaned and disinfected between each use. Gait belts should not be worn around the waist of rehabilitation staff or (if cloth) used on multiple patients due to the inability to clean the gait belt between patients. Vinyl gait belts are available that can be cleaned between patients, but can be less reliable as an assistive device due to their tendency to slide. If equipment is designated for single-patient use, there is still a need to clean and disinfect the equipment on a regular basis. Cleaning and disinfecting supplies need to be made accessible to staff in order to facilitate the cleaning process. Attaching brackets to larger pieces of equipment that hold disinfecting wipes is a convenient way to make this possible.

Treatment mats and positioning wedges should be disinfected between uses and inspected for any cracks or tears that compromise the integrity of their covers. Pillows need to be wiped down daily and as needed. Paper pillow covers should be changed between patients and as needed when body fluids are present. Proper handling and storage of clean and dirty linens should be maintained in both the clinical and therapy areas as necessary. Another challenge for the IP in rehabilitation is maintaining appropriate disinfection practices within simulation environments such as "therapy apartments" used to evaluate the patients' ability to function on their own. Activities of daily living such as cooking are actually performed within these settings, requiring greater attention to detail when establishing facility cleaning and disinfection policies. Dishes and equipment used in therapy kitchens should be washed in a dishwasher or cleaned according to state food code guidelines.[35]

The use of hydrotherapy, whirlpools, and aquatic therapy pools in the rehabilitation setting is of great benefit to patients for the treatment of wounds, pain, and immobility. It is also beneficial for relaxation and recreation. However, water can be a source of and vehicle for transmission of infectious organisms. Maintaining the proper levels of disinfectant in pools can help control organic load. Some patients may have to be excluded from these types of therapies due to open wounds or the inability to contain fecal matter. State guidelines for public and private pools need to be followed for cleaning and chemical use in the pool areas. Immersion tanks and whirlpools need to be cleaned with the appropriate disinfectant and following manufacturer's recommendations. Equipment with agitator jets must be disinfected with the solution covering the jets and circulating through the jets while disinfecting.[36] Logs should be maintained of the results of water testing and remediation as required by state and local law. Presence of the therapy pools and spas should be included in the infection control risk assessment and appropriate screening (for waterborne illness, *Legionella*, etc.) should be performed as indicated.

Augmentative Communication

Speech and occupational therapies are moving toward using more technology in their therapies and treatments for patients. One area, augmentative communications, utilizes devices such as eye-tracking hardware, voice simulators, and, most recently, iPads for patient use. The challenge has been how to incorporate such devices into a medical setting that do not come with manufacturer recommendations conducive to the disinfection requirements of patient-to-patient use. The CDC's *Guideline for Disinfection and Sterilization in Healthcare Facilities*[34] provides the basis for developing common sense policies to maintain safety for the patients and HCP.

A recent article addresses the need for guidelines for the safe use and disinfection of mobile handheld devices.[37] Solutions for protecting the device while providing a barrier range from containing it in a simple, disposable plastic zippered bag to the use of a military grade waterproof or water-repellant cover. Some manufacturers of cases have been proactive in testing their products for performance with common hospital-grade disinfectants.[38] Key policies for the IP to establish regarding touch devices are requirements for hand hygiene before and after use of the device, methods for disinfection of the device or providing a barrier, when to replace that barrier, establishing a disinfection interval (when visibly soiled, on a routine basis, between patients, and at the end of the day), any necessary adjustments for patients on Contact Precautions, and how to deal with HCP's personal devices when used with patients or in treatment areas within the workplace.[37]

However, inappropriate use of liquid on electronic medical equipment has been known to cause fires, explosions, electric shock, malfunctioning of the equipment (which risks life-threatening errors such as loss of ventilation, over-infusion, or burns), and HCP injury. Spraying the equipment with disinfectants and/or wrapping the item in cloths soaked with disinfectant has been associated with the solutions penetrating the housings and corroding electronic circuitry.[39] Avoiding contamination in the first place by employing barriers is a key workflow control to avoid problems.[37,38] Providing guidance to staff regarding knowing when a device needs to be cleaned versus disinfected is paramount for the IP and should be achieved via policies and regular educational activities such as upon hire, with the addition of any new equipment or cleaning product, and during yearly required safety instruction.[39]

A collaborative response from the U.S. Food and Drug Administration (FDA), the CDC, the Environmental Protection Agency (EPA), and Occupational Safety and Health Administration (OSHA)[39] has weighed in on hazards when cleaning electronic equipment and advises the following strategies:

- **Identify the equipment for which this notification applies**
  - Obtain the manufacturer's labeling which may include information attached to the equipment, instructions accompanying the equipment (such as the user manual), and information on the manufacturer's website.
  - Review the labeling for any cautions, precautions, or warnings about wetting, immersing, or soaking the equipment. If you find any of these, then this notification applies to that equipment.
- **Review the manufacturer's cleaning and maintenance instructions and ensure all staff are trained and will follow these instructions.**
- **Protect equipment from contamination whenever possible.**
  - Use engineering controls and careful work practices to avoid contaminating the equipment. Such work practices generally include:
    - Avoiding unnecessary touching of the equipment during care delivery, especially with contaminated hands or gloves;
    - Positioning equipment to avoid contact with anticipated spatter; and
    - Avoiding laying contaminated items on unprotected equipment surfaces.
  - Use barriers on equipment surfaces that you expect to touch with contaminated hands or when contact with spatter cannot be avoided.
- **If there is suspicion of equipment contamination with microorganisms that might pose a transmission risk in healthcare settings (e.g., those requiring Contact Precautions), do the following:**
  - Clean equipment surfaces in accordance with instructions from both the equipment manufacturer and the chemical manufacturer.
  - If disinfection is necessary, alternative strategies to avoid wetting should be explored in consultation with the equipment manufacturer.
- **Always adhere strictly to all the chemical manufacturer's warnings, precautions, and cautions, and carefully follow all directions for use. (See Appendix III for OSHA definitions.)**
  - The manufacturer's directions for use are the primary source for information on disinfectants. All relevant federal regulations, recommendations, and guidelines support and promulgate this position. This includes information on how to apply disinfectants to the equipment and the time required to achieve disinfection.
  - All manufacturers of regulated medical equipment and disinfectants are required to include adequate directions for use of their products. If directions for use are not included with the equipment or disinfectant, obtain the directions from the manufacturer(s).
  - It is a violation of federal law (Federal Insecticide, Fungicide, and Rodenticide Act [FIFRA 7 USC § 136 et seq.]) to use a disinfectant in a manner inconsistent with its labeling. Furthermore, if a disinfectant labeled for immersion is applied by wiping or spraying, then disinfection may not result, especially if the recommended conditions for use (e.g., remaining wet for the required contact time) are not met.
- **If equipment is contaminated with blood or other potentially infectious material (OPIM), the equipment must be decontaminated per OSHA regulations (see Appendix III for the OSHA definition of "contaminated.")**
  - Follow the equipment manufacturer's directions for cleaning to remove as much soil as possible.
  - It may be necessary to remove the equipment from service for thorough cleaning and disinfection.

Other adaptive devices such as sip-and-puff (SNP) controls for call lights and wheelchairs or new innovations, such as inductive tongue-computer interface (ITCI) which control computer screen positioning using tongue movements along a device within the mouth, present the IPs with further challenges in the rehabilitation setting because these devices may be in the semi-critical category, depending on what components come in contact with the mucous membranes and if they are disposable or reused. Manufacturers' guidelines for use and disinfection should be followed.[40]

SURVEILLANCE AND REPORTING

Process Surveillance

Process surveillance involves monitoring the adherence to infection prevention policies and procedures or recommendations during the provision of care to patients.[41]

Examples of process surveillance in the rehabilitation setting include:

- Monitoring compliance with routine equipment disinfection schedules in a therapy gym;
- Observing proper asepsis is maintained during central line care;
- Monitoring Transmission-based Precautions/proper PPE use with patients identified with MDROs whether on the unit, during transportation, or in a therapy session;
- Ensuring shared equipment such as lifts and scales are properly cleaned and disinfected as indicated between patients and/or at regularly scheduled intervals per facility policy;
- Monitoring facility-level or unit-level device utilization ratios for indwelling urinary bladder catheters.

Data from process surveillance should drive educational interventions, trigger policy and procedure review, and provide timely feedback to clinical and administrative staff. It is important to have good communication with representatives from all departments, including allied health, in order to maintain continuity of the infection prevention and control program across all disciplines.

Outcome Surveillance

Depending on the facility, active surveillance cultures may or may not be performed upon admission. Some facilities take the screening results from the referring facilities as their baseline. However, in a 6-month prospective study to determine the prevalence of and risk factors for MRSA colonization, admission cultures were obtained from new patients on a geriatric rehabilitation unit. Seven percent of the newly admitted patients were found to be MRSA positive, with 95.8 percent of these isolates found being the first positive screen for the patient.[42]The outcomes measured for the patients identified as colonized did not identify significant morbidity or increase in length of stay.[42]With vulnerable populations within a rehabilitation facility, active surveillance screening may be warranted if the infection control risk assessment determines a high incidence of the isolates in the community or referring hospitals. Data from outcome surveillance should be included in the facility's yearly infection prevention risk assessment and may result in adjustments to the priorities of the infection prevention and control program.

Public Reporting

Patients are typically admitted after an acute care stay. The inclusion of rehabilitation units in NHSN reporting introduces another layer of complexity to infection attribution, transfer rules, and definitions of community-associated infections versus HAI.[14,43]The IP utilizing data-mining software needs to verify that

the definitions for identified HAIs and community-associated infections properly account for patients transferred from acute care facilities.

The IRF setting has a unique set of rehabilitation impairment group codes (RIC) by which patients are categorized according to aspects of their diagnoses and standardized for submission to the CMS.[21] This offers the IP opportunities to develop correlation of surveillance data with these standardized measures for the IRF setting, and the potential for research and publication using this standardized nomenclature for the rehabilitation setting. This should not, however, replace the IP's review of the clinical information to determine HAIs. In a 2010 position paper, APIC expresses the concern that administrative (coding and/or billing) data alone not be utilized for HAI surveillance.[44] APIC further encourages the adoption of electronic surveillance support, which should encourage IPs in the rehabilitation setting to dialogue with vendors and developers of electronic surveillance and data mining products about the unique challenges the rehabilitation setting presents when utilizing their products and advocate for the development of features to better capture meaningful surveillance for specialty populations throughout the postacute continuum of care.[44,45]

One common measure tracked by IPs is the prevalence of *Clostridium difficile*infection (CDI) within their facilities. Depending on how this is done, the facility may be reporting facility-wide inpatient laboratory-identified events to NHSN,[3] and may be doing so utilizing data-mining software. NHSN builds in a calculation for community- or healthcare facility-onset which does not take into account that, for the most part, rehabilitation patients are transferred directly from another setting.[43] Since often the report received from the transferring facility contains summary data rather than actual copies of cultures and dates, the ability of the IP to discriminate the presence of a previous test from the same care episode (but outside their facility) is very limited and presents additional workflow issues that are counterintuitive to electronic data mining.

The reporting of cases discovered in the rehabilitation setting utilizing this measure may be inadvertently assigning the wrong attribution, and the data may not be appropriate for planning and evaluation of the rehabilitation infection prevention and control program. A recent article discusses the conundrum of using such a measure to monitor the infection prevention and control program of a facility. Stating that although the exact incubation period for CDI is not definitively known, the exposure to antibiotics has been determined as a risk factor and should be the focus of attribution.[46] The author justifies his claim that it is the antibiotic stewardship efforts of the referring facility that influences the development of the CDI in the postacute care setting, and therefore there should be a better way to attribute these infections to their source, rather than the location of the patient when the CDI was detected.[46] A 2013 study of the prevalence of infections in long-term care populations in the United States noted that there was a greater incidence of infection noted in those with a stay of less than 90 days in the postacute care setting, and in those who had a hospital emergency room visit (17.3 percent vs. 11.3 percent) or a hospital admission (19.6 percent vs. 11.2 percent).[47]

Interfacility Reporting

Patients in a rehabilitation facility generally are transferred from an acute care setting, often after surgery, an ICU stay, treatment with antibiotics, being intubated, having a central line, or having a urinary catheter. A study of patients admitted to a rehabilitation unit from acute care showed 12 percent had a urinary tract infection (UTI) upon admission, with a high correlation with urinary catheter use in

acute care.[48] It is widely documented that there is a gap in communications during care transitions—one that can potentially impact the rehabilitation course of the patient or even result in acute discharge/readmission.[49,50] Therefore, the IP must have good communication with the clinical referral liaison and the IPs and the referring facilities. As required by regulatory agencies, the IP must notify the referring facility of any discovery of the presence of an organism of significance (e.g., MDROs) detected upon admission. Additionally, any identified surgical site infection should be communicated to the operative facility and the surgeon should be notified. Collaboration with the wound care and ostomy nurse can achieve appropriate, timely communication of these discoveries. Keeping a log with the dates, times, and names of the other IPs notified regarding which organism and patient is a necessary activity that often comes up during regulatory site visits.

SURVEILLANCE IN SPECIALTY POPULATIONS

In the rehabilitation population as a whole, there are many specialty populations with unique needs and characteristics that affect their risk for and response to infection. In order to perform meaningful surveillance in these specialty populations, a thorough understanding of these unique characteristics and how they relate to traditional methods and surveillance definitions is required.

Geriatric Patients

Immunosenescence, or the age-associated changes in the immune system, explains some of the increased incidence of infection in the elderly population. The thymus, one of the master glands of immunity, shrinks as the phagocytic ability of neutrophils decreases and the number of natural killer cells increases—showing impaired cytotoxicity and contributing to inflammatory processes.[51] $CD4^+$T cells produced in old age respond poorly, explaining why vaccinations have less efficacy in the elderly.[51] Fever response is blunted, making many of the surveillance criteria less sensitive for detection of infection in the geriatric population.

A study of elderly women (ages 85, 90, and >95 years old) diagnosed with UTI, utilized assessment tools such as the Mini-Mental State Examination (MMSE), Organic Brain Syndrome (OBS) scale, and the Geriatric Depression Scale-25 (GDS-15) and found a positive correlation (odds ratio [OR] =1.9) between UTI and delirium—supporting recommendations that mental status changes can be associated with UTI in the elderly.[48] The revised McGeer definitions for the LTC environment[52] provide excellent guidance as to how to measure confusion and other constitutional changes in patients to predict those with an infective process under way versus those who do not.

Spinal Cord Injury Patients

Spinal cord injury patients with impairment of sensation technically cannot be symptomatic (flank pain, suprapubic tenderness) with a CAUTI, according to NHSN surveillance definitions, without the presence of a fever.[14,43] The 2009 IDSA guidelines for diagnosis of CAUTI state that acute hematuria, rigors, altered mental status, malaise, or lethargy without an underlying cause are also diagnostic criteria to consider for the general patient population; and that increased spasticity, autonomic dysreflexia, or sense of unease are signs in patients with spinal cord injury.[53] These additional criteria in patients with spinal cord injury are also supported by the National Institute on Disability and Rehabilitation Research (NIDRR).[54] It is not recommended to screen patients with catheters for CAUTI without clinical indications.

It is also helpful to note that these guidelines support (after symptoms of a CAUTI event are noted) the removal of a catheter that has been in place longer than 2 weeks and either obtaining a midstream

voided sample (if the catheter is no longer indicated) or obtaining the sample from the freshly placed catheter prior to initiating antibiotic therapy.[53]

Despite the potential for underreporting, there is still the possibility of mistakenly shifting the focus from the source of the infection to the population in which it is prevalent. One study asserted that high prevalence rates of HAIs in rehabilitation facilities are due to UTIs in spinal cord injury (SCI) patients (overall HAIs 21.8 percent in SCI vs. 4.3 percent in the rest of the patients, $p<.00001$; UTIs, 19.2 percent in SCI vs. 4.3 percent, $p<.00001$); with the only statistically significant independent risk factor being the presence of an indwelling catheter (OR = 11.64; 95 percent confidence intervals [CI] 2.53 to 53.65; $p= .002$).[55] This suggests to the astute IP that it is the high prevalence of catheters in the spinal cord patient population that is the true risk factor, rather than the SCI itself.

After an SCI occurs, with the body attempting to maintain homeostasis, an increase in body temperature is common. Due to loss of vasomotor tone, a patient with quadriplegia may be unable to maintain a desirable central temperature when environmental temperatures fluctuate. Patients with SCI, therefore, need to be monitored closely for alterations in body temperature that might be signs of infection.

Patients with Cognitive or Speech Issues

Patients with stroke, dementia, developmental delays, brain injury, or aphasia may not be able to verbalize symptoms of infection.[56]

BLADDER MANAGEMENT

Bladder management is a major objective in the rehabilitation setting and often goes hand-in-hand with mobility and functional independence goals. In a 2010 sociodemographic study, severe impairment of activities of daily living (specifically the inability to walk unassisted) was associated with urinary incontinence in women. The study suggested early detection and rehabilitation as interventions to prevent, delay the onset, or improve existing urinary incontinence in women older than 65 years.[57]

Interestingly, cognitive function or impairment was not as significant a predictor of urinary incontinence as mobility.[57] Another study regarding new-onset of urinary incontinence showed an odds ratio of 4.26 (95 percent CI 1.53 to 11.83) times higher risk of developing urinary incontinence persisting after discharge if continence aids such as adult diapers were used during hospitalization.[58]

UTIs are the HAI with the highest incidence in the rehabilitation patient population.[43,47] Catheter-associated UTIs are addressed elsewhere in this text, and principles of appropriate indwelling urinary catheter usage should be applied to the rehabilitation setting. In a 2011 study comparing rehabilitation nurses' selection of an appropriate reason for a catheter to medical/surgical nurses' selections, half of the rehabilitation nurses selected 24-hour urine collection.[59] This was the only case where the rehabilitation nurses chose an inappropriate reason for indwelling catheter use. However, the rehabilitation patient may have neurogenic or chronic conditions of the bladder that complicate the management of urine without invasive procedures.

Urodynamic Examination

Oftentimes, rehabilitation facilities will have on-site clinic facilities in which to perform urodynamic studies on patients with spinal cord injuries, lower motor neuron dysfunction, or other bladder-related conditions that require diagnostic investigation. Asepsis during this invasive procedure is important, so as not to

introduce pathogenic bacteria into the sterile bladder of the patient.[21] Some facilities require prophylactic antibiotics to be administered prior to the procedure. However, in a study of 133 SCI patients that underwent urodynamic examination, the overall incidence of UTI postexamination was 15.79 percent, with 32.5 percent of those who had significant bacteruria prior to the exam developing UTI 3 days later, where 8.6 percent of those with sterile bladders preexamination developed UTI 3 days later. Further analysis showed a correlation between those with reflex emptying of their bladders and developing UTI at 14.28 percent, guiding the idea that targeted prophylaxis for those with significant bacterial counts prior to exam and those with reflex voiding being at highest risk for developing UTI after urodynamic examination.[21]

Intermittent Catheterization

Intermittent catheterization is a topic of significant importance to the rehabilitation setting. Because of the patient population and nature of rehabilitation diagnoses, promotion and instruction on how to perform intermittent catheterization is a common component of the rehabilitation patient's plan of care. Although studies have indicated there is little difference in the incidence of infection with either clean or sterile technique for intermittent catheterization,[4] it is recommended for aseptic technique to be utilized by HCP due to the possibility of introducing healthcare-associated organisms during the procedure.[60] There are no randomized, controlled trials comparing sterile versus clean in the outpatient setting, and the ones done in the inpatient setting. In cases where parents or caregivers are performing the intermittent catheterization, it is also recommended that they use sterile equipment to reduce the risk of introducing nonindigenous flora from the skin into the patient's bladder.[60] Of note, some of the studies do not distinguish between aseptic technique with a new catheter or clean technique with a new catheter.

Past recommendations for home intermittent catheterization encouraged reuse of catheters. However, some experts have argued that there is no reliable method to recommend for the repeated, reuse of the same catheter for multiple catheterizations.[61] Current disposable catheter manufacturers' labeling and instructions indicate that they are for single use only. The Veterans Administration in 2007 issued a statement that manufacturers' recommendations for single-use catheters should be followed; single-use devices should not be reused in any setting; patients, families, and caregivers should be educated with the same instructions; and patients should be provided with enough supplies to allow for the use of a sterile catheter with each use.[62] The 2009 ISDA International Practice Guidelines discuss the levels of evidence for various practices such as clean versus sterile and single versus-use multiuse catheters.[53] This is mentioned to ensure the IP knows the history of the teaching in rehabilitation and the discrepancies in the available guidelines in order to be prepared to dialogue with those who may question a particular recommended practice.

For the rehabilitation setting, it is important to know the types of catheters available and their advantages and disadvantages based on the individual patient's situation. There may be a significant difference in cost of materials between the products used for training versus the standard products used for routine procedure by HCP. In a prospective, randomized, multicenter trial comparing hydrophilic-coated catheters for intermittent catheterization compared to noncoated catheters in patients with acute SCI, it was found that the hydrophilic-coated catheters delayed the onset of symptomatic UTI (33 percent decrease in the daily risk) and reduced the incidence of antibiotic-treated symptomatic UTIs by 21 percent ($p < .05$).[63]

For the IP responsible for the rehabilitation unit, understanding the importance of preparing the patient for the routine they will be performing at home is necessary when drafting policies governing the standard procedures for performing such tasks. Ready references to teaching materials and access to the latest research on this controversial topic is crucial.

Maximum bladder volume recommendations vary; some offer 500 mL as the maximum whereas others advocate not exceeding 400 mL.[60,62] Catheterization schedules should be adjusted to accommodate keeping the bladder volumes under the recommended maximum to avoid muscle taxing, obstruction of blood flow, nerve damage, stone formation, and ultimately infection.[60,62] The IP must be aware of the dangers of the improperly managed bladder emptying of the spinal cord patient which can induce autonomic dysreflexia or, over time, renal damage.[53]

Indwelling Urinary Catheters

Some patients may be chronically dependent on an indwelling urinary catheter, or some may require the urinary catheter temporarily during their recovery. Leg bag collection devices are commonly utilized in the rehabilitation setting for the ease of mobility during therapy sessions. No guideline for the use of leg bags is currently available;[4] however, to decrease the risk associated with leg bags, the following recommendations are assembled from rehabilitation literature or were included in the *2008 SHEA/APIC Guideline: Infection Prevention and Control in the Long-term Care Facility*[31,42] (See Table 66.1).

Other Methods for Urinary Collection/Containment

Wound, ostomy, and continence nurses are a great resource for the patient requiring urinary diversion/collection methods such as urostomy or suprapubic catheters. The decision to have a suprapubic catheter for a spinal cord patient is often one made with the consultation and support of the rehabilitation team after individual lifestyle and health status considerations are addressed. Fit, shape, and surrounding skin should be assessed for any signs of breakdown whenever dealing with ostomy sites. Barrier skin preparations are available to protect the surrounding areas from maceration. It is important to evaluate the site frequently, especially in populations with decreased sensation or cognitive awareness.

Table 66-1 Leg-Bag Recommendations

Recommendation	Rationale
Choose a product with an antireflux valve, if available*	Decreases the reflux of urine from the bag back into the bladder during activity
Choose a product with an adequate storage volume and specify emptying frequencies individualized for the patient	Leg bags with smaller capacity (especially without an antireflux valve) could back up into the bladder, precipitate autonomic dysreflexia, or cause storage malfunction during a therapy session
Use aseptic technique when disconnecting and reconnecting	Introduction of bacteria is likely during breaks in the closed system.
Use alcohol to disinfect connections	Potentially reducing the bacterial load at the site of connection disruption
Secure catheter to the leg with a stat-lock type device	CAUTI elimination bundle recommendation

*Currently there are limited options for leg-bags with antireflux valves and sterile sampling ports.

Condom catheters are a good option for urine collection in the male rehabilitation patient with incontinence issues. The condom catheter provides containment of urine and protection of skin and clothing with less risk than is associated with the indwelling catheter in most patients. It should be noted that a sevenfold risk reduction in the incidence of UTIs has been observed in patients with SCIs utilizing condom catheters versus indwelling urinary catheters.[64] However, there is still risk to the skin with their use. Hypersensitivities to the materials, latex allergies, prolonged use of adhesives, or damp skin can all cause potentially serious complications.[64] Proper sizing and fit should be assured of both the catheter and the collection bag—ensuring it is secured so as not to provide counterpressure against the area of adhesion to the skin. Skin necrosis, urethrocutaneous fistulas, and penile strangulation have been reported with their use.[64] The condom catheter should be removed and replaced every 24 hours to avoid associated increased risk for UTI. Products may include an antireflux valve, adhesion options, or securing with balloon inflation concept.[64] It is recommended to obtain necessary urine samples between catheter changes, after hygiene has been performed. There is a special system available for patients utilizing intermittent catheterization without disturbing the adhesive of the condom catheter. These systems come in two pieces, with a removable tip that can be replaced after intermittent catheterization is complete.[64]

As mentioned previously, the use of incontinence devices such as an adult diaper in the hospital is associated with new-onset urinary incontinence that persists beyond hospitalization.[58] Therefore, timed voiding, prompted voiding, double-voiding, fluid restrictions after a certain hour, and bladder diaries are all techniques to encourage bladder training for continence.[65]

BOWEL MANAGEMENT AND GASTROINTESTINAL SYMPTOMS

Restoring normal or regulating neurogenic bowel function is an important aspect of the specialty of rehabilitation nursing.[7] After a long course of hospitalization, immobilization, poor nutrition, possible barium studies, and narcotic pain medications, many rehabilitation patients arrive to the facility either impacted or severely constipated. Rehabilitation nurses establish care plans to relieve impaction and avoid continued constipation. These care plans can involve the use of bowel stimulants, stool softeners, and other laxative medications.

Although introduction of medications should be done slowly and carefully, sometimes the resulting patient reaction is diarrhea or fecal incontinence episodes. It is important for the IP doing surveillance for *C. difficile* or other causative agents of infective gastroenteritis to be aware of the addition of any new medications, new fiber increases, or adjustments to the bowel plan of care. Caution should be used whenever a patient presents with loose or liquid stools, however, because the HCP could erroneously attribute the symptoms to medications when the patient truly has an active infectious diarrhea, and inadvertently delay testing, initiation of precautions, and proper treatment. Therefore, patients with loose or watery stools should be placed on Contact Precautions until an infectious process is ruled out. A suggestion to reduce the number of days patients are in precautions due to noninfectious diarrhea is to have some delineation in the facility's policy between suspected and confirmed cases of infectious diarrhea. Some facilities utilize the term *enteric precautions* for the entire scope of symptoms or diagnoses involving diarrhea and vomiting, whereas others specify *C. difficile*, rotavirus, norovirus, etc. in

their Contact/Transmission-based Precautions orders. Distinguishing between confirmed and suspected in the Contact Precautions order may allow for clearer discontinuation algorithms and result in fewer days spent in precautions. A bout of *C. difficile*can significantly impair the functional status of the patient and impede upon goal attainment of independence and return to community; attention to the environmental components of the transmission of *C. difficile*is an essential secondary prevention strategy to facilitate successful rehabilitation.[66]

In some rehabilitation patient populations, such as patients with SCI, multiple sclerosis, or stroke, establishing a *bowel program*may involve interventions that can be quite invasive such as transanal irrigation (TI)[67]or pulsed irrigation evacuation (PIE), which involves the use of what is classified as a medical bowel prosthetic device.[68]In a study of the efficacy of TI versus conservative bowel management, it was found that TI improved fecal incontinence and necessitated fewer clothing changes and less clinical time spent on the bowel program.[48]Use of the PIE machine was found to help avoid dangerous autonomic dysreflexia episodes in SCI patients while containing the waste products in a convenient, disposable closed-system.[68,69]The IP should be aware of these options and devices as they may be called upon with questions regarding product choices, safe operation without cross-contamination, and cleaning and disposal of waste products. It is recommended that only trained HCP operate these devices in compliance with manufacturer instructions and facility policies.

SKIN INTEGRITY AND WOUNDS

Factors such as incontinence, skin breakdown, comorbidity, and age are all associated with increased risk of infection in the rehabilitation population. Immobility that occurs with an injury or illness alone puts the patient at risk for impaired skin integrity. Illness or injury may also cause a decrease in the sensation of pain and pressure. Invading bacteria can infect cuts and burns, as well as wounds caused by prolonged pressure, arteriosclerosis, or poor circulation. Maintaining skin integrity and management of wounds are major considerations in rehabilitation. Because the skin acts as a biologic barrier between a person and the environment, failure to maintain skin integrity may cause increased risk for infection and may extend the length of stay for the rehabilitation patient.

To decrease the risk of wound infections, a comprehensive team approach must be used in the rehabilitation setting. Facilitating personal hygiene with the use of adaptive devices, ensuring proper positioning, and increasing the patient's mobility can help prevent pressure sores and promote wound healing. If available, the wound care and ostomy nurse works with the rehabilitation team to create a plan of care for the management of complex wounds and ostomies. Collaboration between the wound care, ostomy nurse, and the IP is important in identifying and monitoring wound infections and providing education to the staff regarding proper technique for the care of individual patients' needs.

An example of collaboration between IP and wound care nurses in the rehabilitation setting would be establishing an evidence-based practice for the routine pin-site care of external fixators. The care of a patient in a halo vest or with external fixator devices can be difficult for staff to perform or teach to families in the rehabilitation setting, making providing sound guidelines an important task.[70]The IP could perform a review of the literature and find a consensus that an alcoholic chlorhexidine product utilized with a nonshedding applicator to clean the pin sites is recommended, with no difference in infection rates when performed weekly versus daily.[71,72]The IP could then make a recommendation to the wound care nurse regarding available products based upon these findings, while the wound care nurse could

draft the procedure for performing the cleaning and application of dressings as needed per the individual patient's needs for containing drainage.

A number of additional factors associated with aging or disability can alter the characteristics of the skin, predisposing the patient to increased risk for infection. These include issues such as:

- Loss of sensory receptors in the skin
- Decreased inflammatory response
- Decreased ability to regulate heat
- Increased capillary fragility
- Decreased hydration of the skin, which can lead to dryness and itching
- Increased risk of skin breakdown and infection

(See **40. Geriatrics**, for more age-related information.)

RESPIRATORY CONCERNS

Some patients are admitted to the rehabilitation facility needing respiratory therapy care due to impaired respiratory function. When patients have weakened respiratory muscles and cannot cough or breathe deeply enough, secretions that are normally produced in the airway become excessive. Infections of the lower respiratory tract become an issue.[65,73] Patients are also admitted to rehabilitation facilities to receive speech and swallowing therapies. As patients are evaluated on their ability to tolerate different consistencies of food and liquid, it is important to maintain surveillance for aspiration pneumonias.

Respiratory interventions, for instance, might include hydration, nebulization, cough techniques, incentive spirometry, percussion, vibration, and postural drainage (see **67. Respiratory Care Services**). Respiratory therapy requires a plethora of equipment for treatment. Some items are not disposable and may be shared between patients. These items need to be cleaned and disinfected as needed between uses. Sometimes even simple noninvasive activities such as singing or light exercise can help with deep breathing and improved respiratory function. Rehabilitation patients with SCI and limited innervations of muscles supporting pulmonary functioning are at high risk for atelectasis and other sequelae of ventilator dependency. Some centers are trying an assistive cough device that helps stimulate clearing of the pulmonary tract.[65]

Patients may require a tracheostomy or mechanical ventilation in the rehabilitation setting. The facility needs to develop and implement written guidelines to reduce and prevent ventilator-associated pneumonias and pneumonias that may be related to having the tracheostomy in place. Some of the recommended practices include peptic ulcer prophylaxis, keeping the head of the bed elevated between 30 and 45 degrees, and meticulous oral hygiene for the patient, including a daily rinse with chlorhexidine mouthwash.[74] Many facilities have an active program for weaning patients from the ventilator and tracheostomy. Nurses and therapists need to use good Standard Precautions when working with the tracheostomy, and sterile gloves and supplies are used when handling anything that will go into the tracheostomy or anything used to clean around it.[75] Keeping the tracheostomy site clean and dry is important, as well.[65] Facility policies should address suctioning, changing the dressings, and how to clean or change out the tracheostomy device. (See further information in **36. Pneumonia**.)

DISCHARGE PLANNING

Successful community reentry is the goal for most of the patients in the rehabilitation hospital setting. Although this may not be appropriate for all patients, it can be successful for patients who are involved in the discharge plan and who are encouraged to take responsibility for their health maintenance plan and their environment after discharge. The patient with an infection in the rehabilitation hospital will be given treatment for that infection. The goal is to have most patients infection-free or device-free when they leave the hospital. However, some patients go back to prior living environments while receiving antibiotic treatment or with a chronic indwelling catheter or other such device. It is important that the patient knows the signs and symptoms of infection and understands steps to take should symptoms arise. Patients who are elderly or neurologically impaired from an accident or illness need to know how signs of infection will manifest for their particular age group or impairment.

As patients with chronic disabilities attempt to reenter the community, they continue to experience barriers and gaps in services. Home and community assessment can help plan for a smoother transition. Community outings for reintegration led by recreation therapy staff can help patients identify and modify barriers that exist for them in the community before discharge. If the patient has an infection that may be considered contagious or has excretions or secretions that need to be contained, the care team can help plan for follow-up care and appropriate community resources. Patients must be given the appropriate education on infection prevention practices to protect themselves, their family and caregivers, and the community.

Conclusions

When patients enter the postacute rehabilitation setting, the services provided vary to meet the needs of the person with the disability. Most patients are admitted with medical conditions that may complicate treatment. The care plan is individualized for each patient with the goals for outcomes specific to the patient's needs. There are a variety of settings in which care can be delivered. Most patients will not be able to recognize or verbalize symptoms of infection in their own bodies. Each patient must be assessed for symptoms of infection on admission and throughout hospitalization. Care must be provided in a manner that is safe for the patient, the other patients in the hospital, and the care team. The need for infection prevention, Transmission-based Precautions, and the potential risks involved in each care setting must be assessed so the care plan can be carried out in a safe and productive manner while maintaining the dignity of the individual. The IP is needed to assist in the development, implementation, and evaluation of policies and procedures to manage and minimize the risks that may be involved in providing comprehensive services across a variety of settings.

Future Trends

Emerging psychoneuroimmunology research on the impact of self-perception and productivity in illness and susceptibility to infection is indicating a role for occupational therapists in primary and secondary prevention.[76]

A 2005 pilot study at the Institute for Rehabilitation and Research in Houston, Texas, concluded that bacterial colonization of the bladder provides interference with developing a symptomatic UTI.[61] Building upon that study, a multicenter randomized controlled trial studying the effectiveness of inoculating the neurogenic bladders of patients with the HU2117 strain of *Escherichia coli* found that colonization with

this strain safely reduces the risk of symptomatic UTI in patients with SCI.[77] Simplified methods for achieving bladder colonization for this purpose are currently under investigation.

Research into new surveillance definitions for UTIs in specialty populations such as SCI patients is necessary to gauge incidence, prevalence, and the scope of the problem. Some research has already been done with varying factors for symptomatic versus asymptomatic UTIs in stroke patients,[61] but more work needs to be done with the identified gaps in measuring symptoms in patients with aphasia.

The use of the medication fidaxomicin, a macrocyclic antibiotic, has shown promise as a CDI treatment alternative to vancomycin (in severe disease) that spares the gut flora, has less renal complications, and results in fewer instances of recurrence—especially in the elderly.[78,79]

International Perspective

International infection prevention concerns in rehabilitation centers and hospitals are similar worldwide. The literature from other countries addresses many of the same challenges faced in rehabilitation centers in the United States. Those issues include, but are not limited to, managing dysfunctional bladders and teaching self-catheterization,[80] addressing the impact of resistant organisms on a patient's rehabilitation process,[24] seeking ways to prevent ventilator dependency and its sequelae,[73] device-associated infections, improving hand hygiene,[81] and improving patient outcomes.

Wazakili et al.[82] reported that in South Africa, some patients received some form of rehabilitation for their disability, but they did not receive sexuality education, and education about human immunodeficiency virus (HIV) and AIDS was not part of the rehabilitation process. The authors concluded that rehabilitation staff needed to extend their scope of education to include the promotion of good sexual and reproductive health for disabled young people.[24]

An interesting study to come out of Germany promises to deliver recommendations for the safe treatment of rehabilitation patients with MDROs by utilizing standard hand hygiene practices and additional measures.[83]

The World Health Organization's guideline for community-based rehabilitation demonstrates the environmental barriers to infection prevention activities in resource-poor areas and considerations for overcoming these barriers.[9]

Supplemental Resources

ADDITIONAL GUIDELINES AND CLINICAL PRACTICE CONSENSUS GUIDELINES

Centers for Medicare & Medicaid Services (CMS). *Nursing home data compendium 2012 edition.* CMS website. 2013. Available at: **https://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/CertificationandComplianc/downloads/nursinghomedatacompendium_508.pdf**.

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Websites

American Medical Rehabilitation Providers Association (AMRPA). Available at: **www.amrpa.org**.

Association of Rehabilitation Nurses (ARN). Available at: **www.rehabnurse.org**.

Brain Injury Association (BIA). Available at: **www.biausa.org**.

Brain Trauma Foundation (BTF). Available at: **www.braintrauma.org**.

Center for International Rehabilitation Research Information and Exchange. Available at: **www.cirrie.buffalo.edu**.

Commission on Accreditation of Rehabilitation Facilities: CARF International. Available at: **www.carf.org**.

National Amputee Foundation. Available at: **www.nationalamputeefoundation.org**.

National Multiple Sclerosis Society (MSS). Available at: **www.nationalmssociety.org**.

National Rehabilitation Information Center (NARIC). Available at:**www.naric.com**.

Society of Urologic Nurses and Associates (SUNA). Available at: **www.suna.org**.

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org

APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Respiratory Care Services

Author(s): Marie Fornof, RN, BSN, CIC
Infection Preventionist

National Jewish Health
Denver, CO

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Abstract

The respiratory care service provides diagnostic and therapeutic procedures to monitor and support respiratory function. Respiratory care service activities may include cardiopulmonary diagnostics, emergency resuscitation, the administration of medical gases and aerosolized medications, bronchial hygiene therapies, airway management procedures, lung expansion therapies, mechanical ventilation, and blood gas sampling and analysis. Each of these procedures is a potential source of infection for the patient or the practitioner. Understanding of these components and potential avenues for introduction of microbes is critical for prevention of infection. Specific respiratory care issues involve proper equipment handling, cleaning, disinfection, and storage of equipment, as well as use of evidence-based practices that reduce the risk of infection to patients, healthcare personnel, and visitors. Application of bundles to prevent ventilator-associated pneumonias has led to decreases in rates.

Key Concepts

- Risk factors for respiratory infections include:
    - Age (premature, young, and elderly persons)
    - Severe underlying disease: respiratory and other chronic illnesses
    - Immune suppression
    - Enteral feeding
    - Thoracic or abdominal surgery
    - Invasive ventilatory support
- Most bacterial healthcare-associated pneumonias occur when organisms colonizing the oropharynx or upper gastrointestinal tract are aspirated.

- Intubation bypasses first-line protective mechanisms in the upper airway and increases the risk of aspiration and subsequent infection of the lung.
- Mechanical ventilation systems are another potential source of infection. When appropriate, practitioners should consider using noninvasive ventilation to reduce the risk of infection.
- Routes of transmission of pathogens most commonly associated with respiratory care are airborne droplet nuclei and direct contact with contaminated fluids, hands, and equipment.
- Routes of transmission may be from practitioner or device to patient, from one patient to another, from patient to caregiver, or from one body site to the lower respiratory tract of the same patient via hands or device.
- Contaminated aerosols are associated with pneumonias due to *Legionella*spp., *Aspergillus*spp., and *Serratiamarcescens*.
- Improperly cleaned and disinfected respiratory care equipment, inappropriate environmental disinfection, or lapses in hand hygiene can all lead to the spread of infection in any patient.

Background

Recent advances in the understanding of transmission of infection by respiratory care service (RCS), equipment, and the use of evidence-based practices are improving patient care and safety and have reduced the incidence of ventilator-associated pneumonia (VAP).[1,2,3]However, a 2009 report on the cost of healthcare-associated infections (HAIs) states that the average cost of VAP each year averages from $19,633 to $28,506 per case and an annual cost of one to one and a half billion dollars.[4]The infection preventionist (IP) is key in helping facilitate implementation of these evidence-based practices. The creation of a local multidisciplinary team is important to develop and implement interventions to prevent pneumonia and other respiratory infections. The IP must also be familiar with the processes used to care for the equipment and monitor that the processes are correctly implemented and followed. This includes high-level disinfection, sterilization, and appropriate use, care, and storage of equipment. VAP surveillance definitions changed to a new algorithm in 2012 and are now known as ventilator-associated events (VAE).[5]

Basic Principles

Many of the same principles that prevent spread of infection in other settings are an important part of the care provided by the RCS department. Concepts of infection prevention are taught using the framework of concepts and procedures that are specific to the services provided by the department. To facilitate best practices in the RCS department, the IP must be able to include the concepts in several other chapters discussed in the *APIC Text*as part of the education and surveillance for the department. These key chapters include:

- **10. General Principles of Epidemiology**
- **21. Risk Factors Facilitating Transmission of Infectious Agents**
- **27. Hand Hygiene**
- **29. Isolation Precautions (Transmission-based Precautions)**
- **30. Aseptic Technique**

- **31. Cleaning, Disinfection, and Sterilization**
- **36. Pneumonia**

APPROPRIATE CARE OF DEVICES USED IN RESPIRATORY THERAPY

The Spaulding classification should be used to determine when devices require low- or high-level disinfection or sterilization. This is discussed in detail in **31. Cleaning, Disinfection, and Sterilization**. A brief outline and discussion of the system will help those working in RCS determine what level is required. To summarize, the classification requires the following:

1. Noncritical devices require low-level disinfection (LLD). Those devices either do not ordinarily touch the patient or touch only intact skin.
2. Semicritical devices require high-level disinfection (HLD). This is the minimal requirement for devices that come into contact with intact mucous membranes and do not penetrate sterile tissue. HLD is defined as the destruction of all vegetative microorganisms, mycobacteria, small or nonlipid viruses, medium- or high-lipid viruses, fungal spores, and most bacterial spores.
3. Critical devices require sterilization. This is the requirement for devices that normally enter sterile tissue or body sites, or those that flow through the vascular system. Sterilization is the destruction of all microbial life.

The Centers for Disease Control and Prevention (CDC) guidelines for prevention of healthcare-associated pneumonia, released in 2003,[6]summarize the following components as important based on the device:

1. General measures:
   a. Clean all equipment and devices to be sterilized or disinfected.
   b. Whenever possible, use steam sterilization or perform HLD for semicritical devices following the procedures outlined in **36. Pneumonia**.
   c. Use sterile water for rinsing reusable devices and equipment if possible. If this is not feasible, use filtered water or tap water followed by a rinse with isopropyl alcohol.
   d. Dry with forced air or in a drying cabinet.
   e. Store to prevent further contamination.
   f. If reprocessing single-use devices, adhere to provisions in the U.S. Food and Drug Administration-s (FDA) enforcement document (see also **32. Reprocessing Single-Use Devices**).
2. Mechanical ventilators:
   a. Do not routinely sterilize or disinfect the internal machinery of the ventilators.
   b. Perform routine LLD of the outer surfaces following manufacturer recommendations, facility procedure, and using an LLD approved for healthcare use by the Environmental Protection Agency (EPA).
3. Breathing circuits, humidifiers, and heat/moisture exchangers (HME):
   a. Unless visibly soiled or mechanically malfunctioning, do not change routinely.
   b. Periodically drain and discard any condensate collecting in the tubing of a mechanical ventilator in a manner that does not allow the condensate to drain toward the patient.
   c. Wear gloves to perform the previous procedure and/or when handling the fluid, and perform appropriate hand hygiene afterward.
   d. High-efficiency bacterial filters are to be used on the expiratory arms of the ventilator circuit. The filters should not be placed between the inspiratory arm of the humidifier and the patient.

4. Ventilator breathing circuits with HMEs:
    a. Change an HME only when it becomes visible contamination or mechanically malfunctions.
    b. Do not change the breathing circuit attached to the HME routinely in the absence of malfunction or visible contamination while it is in use on the same patient.
5. Humidifier fluids:
    a. Use sterile (not distilled, nonsterile) water to fill bubbling humidifiers.
    b. Humidifiers do not need to be changed daily for reasons of infection control or technical performance.
    c. They can be used for at least 48 hours and, with some patient populations, up to 1 week.
6. Oxygen humidifiers:
    a. Follow manufacturers- instructions for use of oxygen humidifiers.
    b. Tubing, prongs, and masks should be single-patient use and changed if visibly contaminated or malfunctioning.
7. Small-volume medication nebulizers, in-line and handheld:
    a. Between treatments on the same patient, clean, disinfect, and rinse with sterile water.
    b. Allow to dry and store in a manner that prevents contamination.
    c. Use only sterile fluid and medication and dispense into the nebulizer aseptically.
    d. Use single-dose medication whenever possible.
    e. If multidose vials are used, follow manufacturers- instructions for storage and use no more than 28 days from date of opening or until the expiration date (whichever is first).
    f. Nebulizers should not be reused between patients without HLD or sterilization.
8. Mist tents:
    a. Between use on different patients, replace mist tents and their nebulizers, reservoirs, and tubing or sterilize or HLD.
    b. No recommendations currently exist about frequency of changing while in use on one patient.
    c. If they are changed for use on the same patient, then perform LLD followed by air drying of the unit.
9. Other devices used in association with respiratory therapy:
    a. Portable respirometer and ventilator thermometers: sterilize or HLD between patients.
    b. Resuscitation bags: sterilize or HLD between patients following manufacturers- recommendations and completely disassembling the bag.
    c. Incentive spirometry is frequently used at the bedside and is single-patient use. If visible secretions are present on the mouthpiece or connecting tubing, they should be cleaned with soap and water, rinsed, and air dried.
    d. Airway clearance devices: most are single-patient use; follow manufacturer-s recommendations for reuse on the same patient.
10. Pulmonary-function testing equipment:
    a. Do not routinely sterilize or disinfect the internal machinery of pulmonary-function testing machines between uses on different patients.
    b. Change the mouthpiece and, if one is in use, the filters of these devices between uses on different patients.
    c. Perform LLD of any surfaces of the equipment handled by the patient between each patient following the manufacturers- recommendations.
11. Bronchoscope equipment:
    a. Clean external ports, surfaces, and internal channels mechanically with water and an enzymatic detergent prior to processing.
    b. Biopsy forceps and specimen brushes are to be sterilized after washing.

c. Follow manufacturers- recommendations for HLD or sterilization.
d. If an automated disinfector is not used to process the bronchoscope, allow disinfectant solution to perfuse through all channels as instructed by the HLD solution-s manufacturer following time and temperature recommendations.
e. Follow appropriate procedure for testing and changing the HLD solution.
f. The endoscope and inner channels should be washed with sterile water or, if this is not practical, then clean tap water followed by an alcohol rinse.
g. The endoscope and inner channels are completely dried using clean, forced air.
h. Store in a manner that prevents contamination of the scope.

APPROPRIATE INFECTION PREVENTION MEASURES FOR COMMON RCS PROCEDURES

In addition to hand hygiene and Standard and Transmission-based Precautions, care should be taken to prevent spread of infection when performing common RCS procedures as follows[7]:

1. Care of patients with tracheostomies:
    a. Tracheostomies should be performed under sterile conditions. Performing them in surgery is preferred, but circumstances and patient condition may dictate that they are performed at the bedside.
    b. When changing a tracheostomy tube, wear a gown, use aseptic technique, and replace the tube with one that has been sterilized or undergone HLD.
    c. Application of antimicrobial topical agents at the tracheostoma is not recommended as a routine part of patient care.
    d. Routine cuff deflation is not recommended.
    e. Ensure proper cuff pressure with minimal leak or minimal occluding pressure.
2. Suctioning of respiratory tract secretions:
    a. Use either a multiuse closed-system catheter or a single-use open-system catheter for prevention of pneumonia.
    b. If saline is installed prior to suctioning, it must be sterile.
    c. No recommendation has been made about the frequency of routinely changing the in-line suction catheter in use on one patient.
    d. If the open-system suction is used, use a sterile, single-use catheter each time.
3. Artificial airways:
    a. Select critically ill patients for tracheotomies if long-term intubation is likely.
    b. Keep head of bed elevated 30 to 40 degrees unless medically contraindicated.
    c. Oral intubation may be preferred to nasal intubation, as the latter is associated with sinusitis.
    d. Routine cuff deflation is not recommended.
    e. Ensure proper cuff pressure with minimal leak or minimal occluding pressure.
    f. Specialized endotracial tubes with suction ports proximal to the cuff allow for subglottic secretion aspiration and do show benefit.
4. Blood sampling and transcutanous monitoring: to ensure safety of the person performing the arterial stick and prevent transmission of infection, the following steps need to be part of the facility procedure:
    a. Use sterile single-patient syringes equipped with safety needles.
    b. Wear exam gloves and, if indicated, mask and goggles (or mask with an attached face shield).
    c. Prep the site thoroughly with a chlorhexidine gluconate (CHG) solution using a back-and-forth scrubbing motion. Allow to dry at least 1 minute. If allergies prevent use of the CHG,

betadine or isopropyl alcohol (70 percent) may be used. The latter solutions may require longer prepping and drying times.

d. Perform the procedure using aseptic technique.
e. Cover the puncture site with sterile gauze squares or bandages when bleeding has ceased.
f. Discard sharps in an appropriate rigid, biohazard container when no longer needed.

PREVENTION OF VENTILATOR-ASSOCIATED PNEUMONIA

Recently, many measures have been developed and researched that have been successful in preventing device-related infections, including VAP. National Healthcare Surveillance Network (NHSN) reports have shown a decrease in rates in many types of intensive care units (ICUs). For example, in the medical-surgical ICU (as defined by NHSN) rates decreased from 3.6 VAP days in 2006 to 1.0 VAP day in 2011 (rate is per thousand ventilator days).[2,8]

Evidence-based practices grouped together are referred to as -bundles- in the healthcare community. In 2008, The Joint Commission adapted a document authored by the Society for Healthcare Epidemiology of America (SHEA) as part of required practices to reduce HAIs due to use of devices or the presence of two specific microbes. Included was a list of guidelines of practices that should be used to prevent VAP.[9]Since then, numerous research studies have been published addressing either one or more of the components that are now included in this document.[10,11,12,13,14]

The recommendations appear as a two-tiered system. The first tier has recommendations that are to be followed by every organization on every ventilator patient and includes:

1. Education of healthcare personnel who care for patients undergoing ventilation about VAP, including:
    a. Local epidemiology
    b. Risk factors
    c. Patient outcomes.
2. Educate clinicians who care for patients undergoing ventilation about noninvasive ventilator strategies.
3. Perform surveillance of VAP, including:
    a. Direct observation of compliance with VAP-specific process measures.
    b. Use structured observation tools at regularly schedule intervals.
    c. Report the outcomes and results to the key stakeholders.
4. Implement policies and practices for disinfection, sterilization, and maintenance of respiratory equipment that are aligned with evidence-based standards (e.g., guidelines from the CDC and professional organizations).
5. Ensure that all patients are maintained in a semirecumbent position unless contraindicated by their medical condition. For the latter, consider using reverse Trendelenburg.
6. Perform regular, antiseptic oral care in accordance with the product guidelines.
7. Unless sedation is medically required, perform a daily sedation -vacation- to establish readiness for weaning to minimize time of mechanical ventilation.
8. Provide easy access to noninvasive ventilation equipment and institute protocols to promote the use of noninvasive ventilation.
9. Establish accountability for ensuring prevention of VAP:
    a. Senior management must support the infection prevention and control program with effective resources and staffing to effectively prevent VAP.

b. Senior management is accountable for ensuring that healthcare personnel are competent to perform their job responsibilities.
c. Direct healthcare providers and ancillary personnel are responsible for ensuring that appropriate infection prevention practices are used at all times.
d. Healthcare and unit leaders are responsible for holding their personnel accountable for their actions.
e. The person who manages the infection prevention and control program is responsible for ensuring that an active program to identify VAP is implemented, that data on VAP are analyzed and regularly provided to those who can use the information to improve the quality of care, and that evidence-based practices are incorporated into the program.

The second tier of recommendations is for places that have an unacceptably high VAP rate despite implementation of the basic VAP prevention procedures described above. In this instance the following special approaches should be implemented:

1. Use an endotracheal tube with in-line and subglottic suctioning for all eligible patients.
2. Ensure that all intensive care unit beds used for patients undergoing ventilation have a built-in tool to provide continuous monitoring of the angle of incline.

Approaches that should **not**be considered routine part of VAP prevention include:

1. Routine administration of intravenous immunoglobulin, white cell-stimulating factors, enteral glutamine, or chest physiotherapy.
2. Routine use of rotational therapy with kinetic or continuous lateral rotational therapy beds.
3. Routine administration of prophylactic aerosolized or systemic antimicrobials.

Performance measures should be developed that are intended to support internal hospital quality improvement efforts and do not necessarily address external reporting needs. However, the IP must keep informed on required and proposed external reporting requirements and update senior management and other key stakeholders. Performance measures should include not only measures of occurrences (e.g., rates of VAP) but also compliance with process (e.g., process measures).

CHANGE IN SURVEILLANCE METHODOLOGIES: VAP TO VAE

RCS personnel should be included in surveillance reports and also given an opportunity to provide input into the measures being collected. They may also be a source of data for the IP. In 2011, new surveillance definitions were planned for what was formerly VAP.[15] A change from VAP to VAEs was finalized and is now the NHSN definition to be used for data collection and entry into NHSN. Even if the facility is not participating in NHSN, it is recommended that NHSN definitions are used, if available, as it provides data for use at the facility or for comparison against other facilities of like nature.

The RCS personnel and IP do need to note that as of January 2014, VAE definitions are only to be used in adult locations and not in pediatric or neonatal locations. VAE is also a surveillance definition and not a clinical definition. Further information on the current surveillance definitions may be found on the NHSN website or in **36. Pneumonia**.

Conclusions

Respiratory care activities present a potential source of infection for patients and healthcare personnel. Personal hygiene is critical. Proper handling, cleaning, disinfection, and storage of equipment can help

protect patients, clinicians, and equipment from contamination during the provision of care and the disposal of expendables. The RCS personnel and IP have many opportunities for collaboration to put the latest evidence-based practices into use for the benefit of patients and the healthcare community. Changes in surveillance definitions need to be incorporated into data collection. Collection of process measures is important to help improve clinical practices.

Future Trends

Research is increasing in collection of process measures that will add to the volume of evidence-based practices and allow the IP to design their program around what is most imperative for their facility. Further research in all elements of the -bundles- will add to the understanding of what can decrease healthcare-associated pneumonias. Of note in the literature summary on continuous lateral rotation therapy was that while at this time it was not seen as part of the VAP bundle, further studies were warranted.[15] Other studies are under way that may add to the bundles that currently exist. The IP must keep current on information that influences the practices of the respiratory care services and be part of multidisciplinary quality improvement efforts in this area.

International Perspective

International efforts to combat HAIs are important and need to be understood, as HAIs due to RCS are not limited to the United States. Recent studies in developing countries are already occurring and show that application of best practices can reduce the burden of respiratory infections related to healthcare interventions.[16,17]

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APIC TEXT OF INFECTION CONTROL AND EPIDEMIOLOGY

Surgical Services

Author(s): Rebecca J. Murphy, RN, MSN, CNOR
Loyola University Medical Center

Maywood, IL

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Abstract

Surgical site infection is one of the top three most-common healthcare-associated infections and may affect the incision, deep soft tissues, or some part of the anatomy (e.g., organs or spaces). Surgical site infections represent the most common healthcare-associated infections for surgical patients. Most surgical site infections result from endogenous or exogenous microbial contamination of the wound during surgery. The risk for infection is influenced by the characteristics of the patient, the operation, the surgeon(s), and the healthcare facility, thus creating a need to have an all-encompassing infection prevention and control program focusing on preoperative, intraoperative, and postoperative interventions. Continued vigilance and strict adherence to aseptic and surgical techniques are required to maintain one standard of care for patients undergoing surgical procedures, given the increasing numbers of ambulatory surgeries, same-day surgery admissions, and minimally invasive surgeries with advanced technologies.

Key Concepts

- Surgical procedures carry the potential for serious or catastrophic complications, including infection; patient care practices should use sound scientific data to reduce both their risk and occurrence.
- Although minimal variation in the distribution and incidence of the pathogens isolated from surgical site infections has occurred in several decades, more of these pathogens demonstrate antimicrobial drug resistance, especially methicillin-resistant *Staphylococcus aureus* as well as emerging and escalating *Clostridium difficile*-associated infections from the abundant use of antimicrobials.
- There must be strict adherence to accepted practices and guidelines that address the prevention of surgical site infections, hand hygiene in healthcare settings, and environmental infection control in

healthcare facilities.

- Collaboration among infection prevention, environmental services, pharmacy, purchasing, perioperative personnel, and organizational leadership is essential in continuous process improvement activities, mutual assessment of new technologies, and implementation of successful change.
- Policies and procedures on cleaning and processing of surgical equipment should be developed, reviewed annually, revised, monitored as necessary, and readily available within the practice setting.
- The basic principles of aseptic technique prevent contamination of the open wound, isolate the operative site from the surrounding unsterile physical environment, and create and maintain a sterile field in which surgery can be performed safely.

Background

The operating room environment is a highly regulated patient service area affected by agencies such as Occupational Safety and Health Administration (OSHA), Centers for Medicare & Medicaid Services (CMS), and state departments of health. The Joint Commission standards and clinical practice guidelines developed by professional organizations, including the American College of Surgeons (ACS), American Society of Anesthesiologists (ASA), and Association of periOperative Registered Nurses (AORN),[1] are integral to effective policies and procedures in the operating room. Related guidelines are also published by the Centers for Disease Control and Prevention (CDC),[2] U.S. Food and Drug Administration (FDA), U.S. Environmental Protection Agency (EPA), Association for the Advancement of Medical Instrumentation (AAMI), American National Standards Institute (ANSI), American Institute of Architects (AIA), and Association for Professionals in Infection Control and Epidemiology (APIC).

The Healthcare Infection Control Practices Advisory Committee (HICPAC) guidelines address the prevention of surgical site infections (SSIs), hand hygiene in healthcare settings, environmental infection prevention in healthcare facilities, and disinfection and sterilization. All CDC guidelines may be found at **http://www.cdc.gov/HAI/ssi/ssi.html**.

Basic Principles

The basic principles in surgical services involve the following:

- With increasing ambulatory surgeries, same-day surgery admissions, and minimally invasive surgeries using laparoscopic, robotic, and imaging technologies, continued vigilance requires a single, safe standard of care for patients undergoing surgical procedures.
- Surgical site infections (SSIs) remain as one of the top three most common healthcare-associated infections (HAIs) and may involve not only the incision(s), but also deep soft tissues, or some part of the anatomy such as organs or spaces.[1,2,3,4] Recently, a CDC prevalence study found SSIs to be the most prevalent HAI.[5]
- SSIs may result from microbial contamination of the wound during surgery.[3,6]
- Endogenous bacteria are the primary source of SSI.[3,6,7]
- Exogenous sources of SSIs include the operating room environment, surgical personnel, or seeding of the operative site from a distant focus of infection.[3,6,7]

- Advances in the stratification of risk factors provide guidance for the development of effective strategies for preventing SSI (see **23. The Immunocompromised Host**).
- Clean surgical wounds have the lowest risk for endogenous microbial contamination and may serve as a tool for measuring the efficacy of aseptic technique in operating room procedures.[3]
- Surgical personnel's adherence to strict aseptic technique and variables related to the skill of the surgeon (e.g., hemostasis, obliterating dead space, and gentle handling of tissue) are critical components in the prevention of SSI.[2]
- As cited in the *Guideline for the Prevention of Surgical Site Infections, 1999,*the risk for SSI is higher, with increased contamination of the site or virulence of the pathogen, and is inversely related to the resistance of the patient.[2]
- The risk for infection is influenced by the characteristics of the patient, operation, surgeon, and hospital.[2]

Prevention and Control of Infection in Surgery

According to data from the National Nosocomial Infections Surveillance System (NNIS), little change has occurred in the distribution and incidence of the pathogens isolated from infections.[8]In 2005, NNIS transitioned into the National Healthcare Safety Network (NHSN) and provides the annual SSI report based on participating facilities' data. More of these pathogens demonstrate antimicrobial drug resistance, especially methicillin-resistant *Staphylococcus aureus*(MRSA).[9]Surgical personnel create and maintain a sterile field in which surgery can be performed, isolate the operative site from the surrounding environment, and prepare the site for surgery.[1]A multidisciplinary approach is necessary for successful infection prevention.[10]

ENVIRONMENTAL CONTROLS

Control of Air Quality and Ventilation

The operating room ventilation system should operate at all times to maintain the air movement relationship to adjacent areas. The cleanliness of the spaces is compromised when the ventilation system is shut down.[11]This is particularly important for ambulatory surgical services, which may operate only on a Monday through Friday schedule and seek to save money by shutting the ventilation system off for weekends and holidays. The sudden activation of the ventilation system in these facilities causes a rapid air turbulence that stirs settled particles to become airborne. For the first surgical patients of the day in these surgical departments, a higher concentration of airborne contaminants may potentially contribute to preventable SSIs. Operating rooms should be maintained at a positive pressure with respect to adjacent areas and corridors;[12]they should not have variable air-handling systems.[12]

Conventional operating room ventilation systems produce a minimum of 15 air changes per hour (ACH) of filtered air for temperature control,[3]20 percent of which must be fresh air.[13]The rationale for these requirements is dilution of microbes and particulate matter and their overall concentration within the operating room environment. Routine monitoring of the operating room ventilation system provides documentation of compliance with the established standards. Regular preventive maintenance to inspect

and clean ductwork, lumens, seams, coils, condensate pans, wet filters, and interior fiberglass lining are some aspects recommended by the National Air Duct Cleaners Association (NADCA).[14]

Enhanced air filtration systems provide a viable option for operating rooms. This technology primarily focuses on a high-efficiency particulate air (HEPA) filter with proprietary adjuncts (i.e., electrical enhancements, ionization, low airflow resistance, ultraviolet light, etc.) to clean and/or purify the air by inactivating and removing airborne particles. The process is germicidal. Their installation is usually within the heating, ventilation, and air conditioning (HVAC) units. Some systems advocate environmentally friendly energy efficiency.

Besides high-efficiency particulate absorption (HEPA) filtration at 99.97 percent effectiveness against particles in the 0.3-μm range, an ultra-low penetrating air (ULPA) filter provides 99.99 percent filtration efficiency for particles as small as 0.12-μm. These filters may be a consideration for healthcare facilities with high SSI rates.[14]

Laminar airflow (LAF) refers to air-handling systems that produce little or no turbulence while directing airflow. The evolution of laminar flow technology has advanced from the initial fiberglass wall packs to HEPA filtration systems to exponential LAF systems. These HEPA-filtered LAFs provide either vertical airflow from ceiling to floor or horizontal airflow in a unidirectional manner across the operating room from a wall-mounted unit, with or without curtains or sliding walls. The exponential LAF systems direct the airflow in an upside-down trumpet flow. Studies regarding the effect of LAF on SSI rates in total joint arthroplasties have failed to definitively prove its efficacy. Numerous initial supportive studies were undertaken on different types of airflow systems; however, numbers were combined or variables, such as surgeon double-gloving, the use of preoperative antibiotics, or the type of socket used, were not controlled for.[15,16,17,18,19] Further studies found the administration of preoperative prophylactic antibiotics to be a less costly means to comparably reduce the rate of SSI in these patients. These preoperative prophylactic antibiotic protocols are currently a national focus through the Surgical Care Improvement Project (SCIP), requiring reported compliance with a standardized protocol (**http://www.jointcommission.org/surgical_care_improvement_project/**). Surgeries performed in conventionally ventilated operating rooms with preoperative antibiotics had rates that were not statistically different from those performed in LAFs.[17,19] This has been reinforced in more recent studies, in which the rates of SSIs were comparable between conventional versus LAF design.[20,21] SCIP reports are verifying a greater reduction in SSIs with protocol compliance. Other interventions should be considered before implementing LAF, including, but not limited to, restricting traffic flow and conversation in the operating room, as well as the routine monitoring of the conventional air system. There is little support for the use of LAF in institutions with procedure-specific SSI rates of 1.5 percent or less.[15]

The use of body exhaust suits in LAF provides patients with additional protection from bacterial shedding, hair, exposed skin, and mucous membranes of operating personnel.[22,23] These body suits also protect the operating room personnel from blood and bodily fluids and particles generated through the surgical procedures—in compliance with the OSHA Bloodborne Pathogen Standard.[24] Although these total body exhaust systems are suggested as another method to aid in the production of ultra-clean air, studies conducted on this topic have included relatively small numbers of joint procedures; are marred by the failure to control for differences in traffic volume into the operating room during the procedure; and have failed to demonstrate a link between reduced microbial air counts and reduced SSI incidence.[25,26] A continual decrease in SSIs, specifically in total joint arthroplasties, has resulted from the use of

LAF with body exhaust suits, prophylactic antibiotics, improved surgical techniques, and multiple other infection prevention measures. A long-term, multicenter, homologous study of surgical cases with the power to determine the isolated effect of a specific laminar flow system would show statistical significance, but is unlikely, despite many total joint surgeons' preference to use laminar flow and body exhaust suits when they are available.[27]

Ultraviolet lighting (UVL) has been proved to possess bactericidal properties.[28] Although UVL does decrease microbial air counts, no demonstrable reduction in SSI rates has been shown. In addition, the studies are limited by their type I errors and nonrandomized, uncontrolled methodology. Factors such as failing to control for a markedly decreased incidence of traffic in and out of the room when using UVL and the highly restrictive protective clothing required limit the interpretation of these studies.[29]

Considering the precautions required to protect staff from potentially harmful UVL, new technologies are emerging in which UVL is being employed in the facility's infrastructure, such as HVAC units. The UVL-HVAC concept is destruction of the microbial cell at point of origin into the facility in a transparent mode to further protect personnel, patients, and others from exposure to the UVL. The combination of UVL and HEPA with or without other components claims microbial destruction, resulting in a clean quality of air for healthcare facilities. Each of these advanced products will require robust study to identify their roles in lowering SSI rates.

Ultraviolet-C (UVC) lights are a new type of ultraviolet energy, employing a 254-nm frequency. The germicidal "C" wavelength targets the DNA and RNA of microorganisms, causing cell death and impacts replication ability.[30] Like UVL, installation in HVAC systems is recommended. Because these are lights, their effectiveness requires that the lights remain on 24 hours per day.[30] Effectiveness and energy efficiency will require further study for operating room adoption.

Misting and fogging technologies claim the ability to sanitize, disinfect, and/or sterilize operating room environments in a specific duration of time. The emitting component is a vapor or gaseous agent (i.e., steam, hydrogen peroxide, oxidation, etc.). The vehicle may be portable mobile units or installed in air-handling systems with or without UVL. Various agencies (i.e., FDA, EPA, ANSI, the American Society of Heating, Refrigerating and Air-Conditioning Engineers [ASHRAE], etc.) clear, register, or certify the products for healthcare use and include effectiveness against microbes (i.e., bactericidal, virucidal, fungicidal, or sporicidal). With some products, the cleaning step must first be accomplished. A major disadvantage with these technologies is the time element, generally longer than the average operating suite turnaround time; thus, optimal use might be for terminal cleaning. Rigorous research studies and comparisons of effectiveness and efficiency will provide the evidence necessary to consider whether these technologies perform as claimed and are beneficial for surgical services.

Consideration should be given to environmental controls for the recovery of laser-generated air contaminants (LGACs) in smoke plumes of lasers or electrocautery equipment.[31] These particles may cause irritation when inhaled and may be of an infectious nature. The National Institute for Occupational Safety and Health (NIOSH) has recommended the control of LGACs by utilizing ventilation equipment to reduce the exposure of operative teams.[32,33]

Traffic Control

Traffic must be controlled to maintain separation of clean from dirty areas, to segregate clean and sterile supplies from contaminated materials, and to ensure that only authorized personnel in

appropriate attire enter the operating room.[6,13]

Traffic zones are established in the operating room based on the principles of aseptic technique.[6]

- In an **unrestricted zone**, personnel in street clothes are permitted and may mingle with those in surgical attire.
- The **semirestricted**zone typically comprises the hallways, offices, and supply rooms adjacent to the operating room. Surgical attire is required for entrance into this zone (i.e., scrub suit, hair covering, and clean shoes or shoe covers, if needed). Patients entering this area are dressed in hospital attire with hair covered.
- In the **restricted zone**—the actual operating room and scrub area—surgical attire and a face mask are required.

The limitation of personnel traffic in the room decreases the amount of bacterial shedding, keeps air turbulence at a minimum, and reduces the accidental contamination of sterile items. Increased personnel in the operating room equates to an increase in the risk of SSIs.[34]Operating room doors should remain closed, except as needed for passage of equipment, personnel, and the patient.

Supplies

Clean and sterile supplies are taken to the operating room from a reprocessing or supply area outside the suite on a covered cart. The dust cover over the cart is removed when the cart enters the surgical suite.[5,6]Supplies are removed from their outside (shipping/transport) containers before entering the operating room. If self-contained case carts are used, they do not need to be covered. Soiled items should be covered in containers or case carts during transport from the individual operating room through the semirestricted zone to a decontamination area for temporary storage until reprocessing. All soiled items must be contained and are not stored in the same area with clean or sterile items.

Proper Surgical Attire

AORN recommends special surgical clothing required for personnel within the operating room suite.[1,3,6]

This attire is typically laundered by an institution-approved laundry, rather than home laundering. The rationale is to contain the microbial flora of the healthcare facility, particularly multidrug-resistant organisms. Additionally, there is an inability to monitor the home laundering process to ensure effectively killing the organisms. The APIC *State of the Art Report: Use of Scrubs and Related Apparel in Health Care Facilities*, first published in 1995 and revised in 1996 and 1997,[35]addresses the many issues involved in healthcare personnel apparel.

Fleece is not acceptable in the operating room. Fleece tends to produce lint, which may raise the particle count of contaminants in the perioperative environment. Fleece also may harbor lint from other fabrics or may collect airborne contaminants. Personnel wearing fleece warm-up jackets in the perioperative environment, therefore, have the potential to place patients at an increased risk for SSI.[36] Three publications discuss the adhesion of organisms to specific fabrics, including polyester fleece.[37]

Hair covering is donned first, so that hair does not fall on clean scrub clothing. Hair coverings cover and contain all hair. Hoods are used to cover facial hair.

Surgical scrub attire is worn to reduce exogenous contamination (shedding) by covering as much of the body as possible. Scrub pants and tops are recommended over dresses to prevent particles shed from the legs and perineum from contaminating the surgical field.[1] Surgical attire should be changed when soiled, contaminated, or penetrated by blood or other potentially infectious materials and at the end of the shift before leaving the facility.

Individuals directly involved with the surgical field don sterile gowns and gloves over their surgical scrubs. These personnel wear gowns that must protect from strikethrough of blood or other potentially infectious materials in accordance with the Bloodborne Pathogens Standard of OSHA. This may necessitate the use of impervious gowns.[24] In 2003, the objective assessment of a gown's level of protection against strikethrough was addressed by the AAMI Standards Board, FDA, and American Society for Testing and Materials (ASTM).

A classification system stratifies the strikethrough properties of gowns into four levels: (1) **level 1 procedures** involve little fluid or pressure, such as dermatology, ophthalmology, and simple ear, nose, and throat surgeries; (2) **level 2 procedures** have an increased amount of fluids and pressure, such as hernias, orthopedic procedures with tourniquets, and tonsillectomy/adenoidectomy cases; (3) **level 3 procedures** involve more fluids and greater pressure, such as mastectomies, arthroscopies, and general surgery operations; and (4) **level 4 procedures** require the highest protection, equivalent to FDA-labeled impervious gowns, for large abdominal cases, orthopedic operations without tourniquets, trauma, cesarean sections, and cardiovascular procedures.[38] When gowning, the gown is considered sterile from the operative area up to within 1 to 2 inches of the neckline and around the sleeves, down to the level of the sterile field, and up to 2 inches above the elbows. In addition to scrubbed persons wearing sterile gowns and gloves, scrubbed persons function within a sterile field. The scrubbed person should don a sterile gown and sterile gloves from a sterile field other than the main instrument table.[1] Because the back of the gown cannot be under constant supervision by the scrubbed person, it is considered contaminated.[6]

Surgical gloves have evolved in material and type. Synthetic gloves have replaced latex and its associated irritation to personnel and patients. Some of the synthetics include, but are not limited to polyisoprene, nitrile, neoprene, and others; however, low-protein, powder-free latex formulations have regained their status as safer and readily available because latex remains the gold standard for barrier, fit, feel, comfort, and economy.[38] The FDA and ASTM D1076 06 have determined a low acceptance quality level of 1.5 for surgical glove, meaning holes.[39,40] Gloves should be worn when contact with blood or other potentially infectious materials, mucous membranes, and nonintact skin could occur. Two methods of gloving are used, as follows:

- **Closed gloving** is defined as the method of donning sterile gloves whereby the scrubbed hands remain inside the cuffs and sleeves of the gown until the cuffs of the gloves are secured over the cuffs of the gown.[6]
- **Open gloving** is defined as the method of donning sterile gloves whereby the scrubbed hands are advanced through the sleeves and cuffs of the gown before placing into the gloves.

The preferred method of changing contaminated gloves is for one member of the sterile team to glove the other. If this is not possible, the contaminated glove should be changed by the open-glove method. Once the original sterile gloves are donned, the gown cuff should be considered contaminated.[1]

Shoe covers do not play a role in prevention of SSIs, but are indicated as possible barriers against body fluid contamination in accordance with requirements of OSHA.[1,41]

A fluid-resistant mask is worn in the restricted zones of the operating room suite.[6]

All jewelry is confined within scrub attire or removed when personnel enter the semirestricted or restricted zones of the surgical suite.[1] Scrubbed personnel remove all jewelry before scrubbing to eliminate the risk of harboring organisms.[2,42]

Healthcare personnel who are in direct contact with patients at high risk (e.g., those in intensive care units or operating rooms) should not wear artificial fingernails or extenders.[2] Natural nail tips should be kept less than 1/4 inch long.

Surgical Skin Preparation

Surgical skin preparation involves the following (see **27. Hand Hygiene**, and **30 Aseptic Technique**):

1. Patients perform or receive preoperative cleansing (i.e., bathe or shower) with an antiseptic agent, preferably with a chlorhexidine gluconate (CHG) formulation because of its persistent properties. Application vehicles for applying the agent to the body, such as a noncotton cloth or sponge, must maintain the concentration of the antiseptic from source to skin for its effectiveness to decrease the patient's endogenous flora. Additionally, permitting the antiseptic, especially CHG formulations, to dry, not be rinsed off, appears to prolong the persistent effectiveness. This preoperative cleansing is more effective when accomplished the night before the operative day[2] and also the morning of the operation to enhance the residual effect of the antimicrobial agent. Antiseptic application vehicles affect the concentration of the agent delivery to the designated sites; product evaluation is essential to verify this.
2. Hair can be cleansed and decontaminated along with the skin. Hair removal techniques increase the risk for SSI. If necessary, clipping just before the time of surgery is the preferred method. This should take place outside the room where surgery will be performed.[2,43]
3. Prepping agents are available based on the procedure.[2] Antiseptics cleared for market by the FDA and labeled as patient preoperative skin preparations should be category I with a primary active antimicrobial ingredient. These antiseptics are fast acting, broad spectrum, and persistent to reduce microbial quantities on intact skin.[44] Alcohol, iodine, iodophors, and CHG formulations are available; however, there is little outcome-based literature to substantiate which antiseptic is the most efficacious in reducing SSIs.[45] Literature does suggest the use of alcohol-based skin preparations reduce SSIs.[37] Alcohol-based skin preps increase the risk of surgical fire; therefore, they must be used as directed.[44] According to the ECRI Institute, there are on average 500 to 650 surgical fires annually in the United States.[46] Proper application method of preoperative skin preparation is essential to reduce the endogenous microbial populations at and adjacent to the incision(s).

Surgical Draping

Surgical draping is defined as the art of covering, with sterile barrier materials, the unsterile area immediate to and surrounding the operative site.[1,6] Sterile fields are prepared for a single patient in a single operating room location where it will be used immediately before the operation. When there is an unanticipated delay or during periods of increased activity and the sterile field will not be used immediately, it may be covered with sterile drapes.[47] Two drapes should be used; the first drape placed with the cuff at the halfway point, and the second drape placed from the opposite side completely covering the cuff of the first drape. The sterile field should be under continual, direct observation to prevent the likelihood of breach in sterility even if the field is covered.

Environmental Cleaning

Surgical lights and the horizontal surfaces of furniture and equipment are cleaned with a healthcare facility-approved disinfectant/detergent and clean cloth.[48] The use of microfiber material for cleaning is recommended. By definition, microfiber is any type of fiber with a diameter of less than 10 µm; however, for its infection prevention capability, a split microfiber of a blend of nylon (polyamide) and polyester is extruded to create a web of ultrafine filaments and microscopic pores.[49] This microfiber technology presents a highly positively charged material (microfiber) that draws negatively charged particles (dirt), withstands hundreds of rounds of laundering, is lightweight, and is more effective in maintaining the concentration of the disinfectant from source to surface application.[50]

The floor is cleaned with an EPA-registered hospital disinfectant/detergent according to manufacturer's instructions.[51] Methods have evolved from cotton mop heads and a single bucket to two buckets, to the wet vacuum, to the microfiber mop. The wet vacuum and the clean microfiber mop head and clean solution are preferred when the floor is visibly soiled.[1,2,50,52] Prepare cleaning solutions daily and replace with fresh solution frequently; use clean mops daily and change frequently according to facility policies and procedures.[51]

At the end of each day's operating schedule, a complete terminal cleaning program is initiated to ensure that every operating room, scrub room, and service room is properly and thoroughly cleaned. The decontamination process begins at the highest level (i.e., light tracks, ceiling fixtures) and progresses downward (i.e., shelves, tables, kick buckets, and floor).[1]

When the sanitation process is complete, the wet vacuum is disassembled and thoroughly washed with a disinfectant.[1]

STERILIZATION AND DISINFECTION

The CDC released the HICPAC *Guidelines on Disinfection and Sterilization for Healthcare Facilities, 2008*. This guidance updates the cleaning, disinfecting, and sterilizing of medical devices and healthcare environments. Inactivating antibiotic-resistant bacteria and disinfecting complex medical instruments (i.e., endoscopes) are addressed.

ANSI/AAMI ST79, comprehensive guide to steam sterilization and sterility assurance in healthcare facilities, addresses the ever-changing technology in sterilization. Definitions of the chemical indicators include the six classes: Classes 1 to 4 chemical indicators, Class 5 integrating indicators, and Class 6 emulating indicators. The latter is defined, but no use and application are included because the industry education removes the biological indicator as a necessary monitoring measure for sterility assurance

level (SAL). AAMI has initiated an annual review process, beginning with ST79-considered the primary authority and source of standards for reprocessing healthcare items; healthcare personnel, central service, operating room, environmental services, and infection preventionists are referred to this source for the latest updates.

AORN *Perioperative Standards and Recommended Practices*are published annually and address disinfection and sterilization practices pertinent to the operating room. Although the CDC, HICPAC, AAMI, ASTM, ANSI, and others are referenced in the recommended practices, AORN details specific applications to the operating room.

Use of Physical or Chemical Agents

Physical sterilization involves dry or moist heat in a gravity-displacement or prevacuum sterilizer. Chemical sterilization employs chemicals, such as ethylene oxide, gas plasma, and hydrogen peroxide (see **31. Cleaning, Disinfection, and Sterilization**).[53]

Selection of Level and Agent

Selection of the appropriate disinfection level and agent for specific items is discussed in an APIC guideline.[54]Thorough cleaning of surgical instruments is critical before accomplishing disinfection or sterilization. Cleaning can decrease the microbial load on surgical instruments to 0 to 10 colony-forming units.[55]

Monitors and Indicators

The use and function of physical monitors, chemical monitors, chemical indicators, and biologic indicators is to verify the effectiveness of sterilization agents and procedures.[53]

Documentation

A comprehensive documentation system should be maintained for monitoring the attainment of parameters of disinfection and sterilization of instruments, in the event of a recall or investigation.[1,6,54]

Anesthesia Equipment

Anesthesia equipment is a potential factor in the transmission of microorganisms. Proper cleaning, disinfection, and sterilization of anesthesia equipment can reduce the risk for infection.[2]Semicritical devices, including reusable anesthesia equipment that comes into contact with mucous membranes, blood, or body fluid, should be cleaned and then processed by high-level disinfection, pasteurization, or sterilization between each patient use. Single-use items (e.g., breathing circuits, suction catheters, endotracheal tubes, stylettes) should be used once and discarded according to facility policies and procedures and appropriate local, state, and federal regulations. When a single-use medical device is reprocessed for reuse by cleaning, repairing, or refurbishing, the FDA considers the device to be "remanufactured," and the entity that reprocessed the device, whether it is the original equipment manufacturer, a third-party reprocessor, or a hospital, is considered to be a "manufacturer." The FDA's final guidance document requires that third-party reprocessors and hospitals comply with all regulatory requirements of the FDA applicable to original equipment manufacturers that reprocess single-use devices for reuse.[56](See **32. Reprocessing Single-Use Devices**.)

Noncritical items (e.g., anesthesia machines, blood pressure cuffs, carts, monitors) that are not in contact with mucous membranes, sterile areas of the body, or nonintact skin should be cleaned/decontaminated when visibly soiled or at the end of the day of use.[54]

Policies and procedures on cleaning and processing anesthesia equipment should be developed, reviewed annually, revised, monitored as necessary, and readily available within the practice setting. Potential hazards for perioperative personnel associated with handling contaminated anesthesia equipment (e.g., exposure to infectious agents) should be identified, and practices should be established to reduce the risk of injury.

Immediate Use Steam Sterilization

Immediate use steam sterilization (IUSS), previously referred to as flash sterilization, is a quick-steam sterilization cycle that does not use the full sterilization cycle of exposure and dry times. Exposure may be abbreviated in gravity steam sterilizers by eliminating wrapping material or using container systems that ensure that the steam has unrestricted access to the instruments.[6]AORN's *Recommended Practices*

[1]are consistent with AAMI, which includes the following:[53]

1. IUSS should be used only when there is an urgent need for the items following the cycle parameters recommended by the manufacturer's instructions for use.
2. When using IUSS, proper procedures must be followed before the sterilization process. These procedures include cleaning, decontamination, inspection, and proper arrangement of instruments in the appropriate containers or trays.
3. The physical layout should ensure direct delivery of sterilized items to the point of use (i.e., close proximity to the operating room).
4. Procedures must be developed to ensure proper aseptic handling and safety of personnel during the transfer of sterilized items. Sealed containers approved by the FDA should be used for transferring the items from the sterilizer to the point of use. Containers will be hot. Personnel should handle with heat-resistant gloves or towels used as "potholders."
5. Implantables should not be sterilized by IUSS.[48]
6. Use of IUSS should be restricted to unplanned or emergency situations, unless there are peer-reviewed, published references supporting expanded usage. Vendor trays should be available to the facility at least hours before surgery to allow for proper inspection of contents, cleaning, and sterilization before surgery.
7. Because it includes no drying cycle, IUSS produces instruments that are hot and wet, thereby compromising most forms of subsequent aseptic transport and storage of sterilized items.
8. Biological indicators are now marketed for prevacuum sterilizers, and rapid results (1 hour) are available.[57]

SPECIAL CONSIDERATIONS CONCERNING TRANSMISSIBLE SPONGIFORM ENCEPHALOPATHIES

Human transmissible spongiform encephalopathies (TSEs) occur in familial, sporadic, and acquired forms. These are: kuru, Creutzfeldt-Jakob disease (CJD), Gerstmann-Straussler-Scheinker syndrome, fatal familial insomnia, and new variant Creutzfeldt-Jakob disease (nvCJD). The most common form of TSEs in humans is CJD, which occurs as both a sporadic and a familial disease. Approximately 10 percent of CJD cases are inherited, caused by mutations in a gene, and about 90 percent of CJD cases are classified as sporadic, with no known source of transmission and no family history. Ninety percent of

the deaths in the United States attributed to CJD are among persons over 55 years of age, with a worldwide death rate of about 1 case per million people per year. The onset of disease is characterized by progressive mental deterioration, unsteadiness and clumsiness, visual determination, myoclonus, and a variety of neurological signs and symptoms. In the terminal stages, the CJD patient is usually aphasic and immobile. Death usually occurs within 6 months of symptom onset. TSEs are fatal and without proven treatment or prophylaxis.[58]

The risk for CJD transmission as a function of tissue type is discussed more fully in **73. Creutzfeldt-Jakob Disease and Other Prion Diseases**.

The FDA's Center for Biologics Evaluation and Research published draft guidance on August 27, 2001, for revised preventive measures to reduce the possible risk for transmission of CJD and nvCJD by blood and blood products.[59]The American Red Cross implemented an expanded blood donor deferral policy for nvCJD (based on the aforementioned FDA draft guidance publication) on October 15, 2001.[60] Currently, nvCJD is not known to have been transmitted by blood transfusion in humans.

The concentration of abnormal prion protein seen in nvCJD lymphoid tissues has led to concerns that nvCJD transmission by blood might be a greater risk than for CJD.[60]The transmission of nvCJD by blood components and plasma derivatives in humans is considered a theoretical possibility. Bovine spongiform encephalopathy (BSE) has been transmitted from one sheep to another by blood transfusion.[59]Another study suggests that the BSE agent can adapt to primate hosts, increasing the possibility of transfusion of nvCJD from a donor who is incubating nvCJD.[60]

The American Red Cross blood transfusion donor policy now defers: (1) donors who have spent time in the United Kingdom for a cumulative total of 3 months or more since 1980, (2) donors who have spent time in any other European country for 6 months or more since 1980, and (3) donors who have received a blood transfusion in the United Kingdom.

The WHO published infection prevention guidelines for TSEs in March 1999.[61]TSE agents are unusually resistant to disinfection and sterilization by some of the most common physical and chemical methods used for decontamination of infectious pathogens. The type and physical state of the infected tissues appear to cause variability in the effectiveness of decontamination. Studies have shown that prions (e.g., scrapie) can exist in the environment for at least 3 years.[62]

Studies evaluating the efficacy of a combination of cleaning and disinfection have not been published. Several researchers found that CJD is incompletely inactivated by 1N sodium hydroxide (NaOH).[63,64,65] Studies have shown that aldehydes, such as formaldehyde, improve the resistance of prions and that pretreatment of scrapie-infected brain tissue with formaldehyde removed the inactivating effect of autoclaving.[64]A formalin–formic acid procedure is needed to inactivate prion infectivity in tissue samples collected from patients with CJD.[61]

Prions exhibit an unusual resistance to conventional physical and chemical decontamination methods. This includes the physical processes of dry heat, boiling, glass bead sterilization, and autoclaving at conventional exposure standards (121°C for 15 minutes) and gaseous decontamination methods with ethylene oxide or formalin.[63,64,65,66]

Several researchers have found complete inactivation of infectivity (>7.4 logs) with the use of NaOH (0.09N for 2 hours) in combination with steam sterilization at 121°C for 1 hour. Extreme caution is needed because this combination may result in potential exposure to gaseous NaOH, extreme heat, or damage to the autoclave.[61]

The safest method to ensure that there is no risk for residual infectivity on contaminated instruments and other material is to destroy them by incineration. Wherever possible, instruments and other materials subject to reuse should be kept moist between the time of exposure to infectious materials and decontamination and cleaning.[65,66]If it can be done safely, adherent particles should be removed with mechanical cleaning to enhance the decontamination process.

Annex III of the WHO guidelines for decontamination methods for TSEs lists the decontamination methods recommended by consultation, beginning with the greatest effectiveness and in order of decreasing effectiveness. When possible, two or more different methods of inactivation should be combined in any sterilization procedure for these agents.

ASEPSIS IN THE SURGICAL ENVIRONMENT

The basic principles of aseptic technique prevent contamination of the open wound, isolate the operative site from the surrounding unsterile physical environment, and create and maintain a sterile field in which surgery can be performed safely.[6]A significant factor in creating and maintaining a sterile field and aseptic environment is the healthcare personnel's surgical conscience. Surgical conscience is an individual's internal value system that motivates correct performance, regardless of whether the person is observed or alone.[6]

Sterility is now defined with a microbiological safety index (MSI). An MSI of 6 (1 × 10^6) indicates that there is a 99.999 percent probability that the product is sterile.[3,6]As the MSI value increases, so does assurance of sterility. Surgically clean is defined as unsterile, with the reduction of microorganisms to a minimal level.[6]

Principles and maintenance of aseptic practice are vital in the operating room. Every institution must develop policies and procedures pertaining to aseptic technique. AORN recommends the following seven practices:[7]

1. Scrubbed persons should wear sterile gowns and gloves.
2. Sterile drapes should be used to establish a sterile field.
3. Items used within a sterile field should be sterile.
4. All items introduced onto a sterile field should be opened, dispensed, and transferred by methods that maintain sterility and integrity.
5. A sterile field should be constantly monitored and maintained.
6. All personnel moving within or around a sterile field should do so in a manner that maintains the integrity of the sterile field.
7. Policies and procedures for basic aseptic technique should be written, reviewed annually, and readily available within the practice setting.

For ensuring surgical hand antisepsis, the CDC *Guideline for Hand Hygiene in Healthcare Settings*has been adopted by The Joint Commission.[67]

The Joint Commission's National Patient Safety Goal 7, which became effective in 2004, includes the requirement by all healthcare organizations to adopt either the CDC or WHO hand hygiene guidelines, implementing all recommendations that are category IA, IB, and IC at a minimum, with consideration of all category II recommendations. A portion of the guideline directs healthcare personnel to do the following:

- Rings, watches, and bracelets must be removed before beginning the surgical hand scrub (category II).
- Debris must be removed from underneath fingernails using a nail cleaner under running water (category II).
- Surgical hand antisepsis using either an antimicrobial soap or an alcohol-based hand rub with persistent activity is recommended before donning sterile gloves when performing surgical procedures (category IB).
- When performing surgical hand antisepsis using an antimicrobial soap, scrub hands and forearms for the length of time recommended by the manufacturer, usually 2 to 6 minutes. Long scrub times (e.g., 10 minutes) are not necessary (category IB).
- When using an alcohol-based surgical hand scrub product with persistent activity, the manufacturer's instructions must be followed. Before application of the alcohol solution, hands and forearms should be prewashed with a nonantimicrobial soap and hands and forearms should be dried completely. After application of the alcohol-based product as recommended, hands and forearms should be allowed to dry thoroughly before donning sterile gloves (category IB).

IMPACT OF RECENT REGULATIONS ON PERSONNEL PROTECTION IN THE SURGICAL ENVIRONMENT

Needlestick Safety

On November 6, 2000, the Needlestick Safety and Prevention Act was signed into law (Public Law 106–430). It directs the U.S. Department of Labor's OSHA to revise the Bloodborne Pathogens Standard to include new examples in the definition of engineering controls. It also requires employers to (1) document plans annually in the exposure control plan to consider and implement safer medical devices, and (2) solicit input from nonmanagerial employees responsible for direct patient care in the identification, valuation, and selection of engineering and work practice controls and document this input in the exposure control plan. It requires certain employers to establish and maintain a record of percutaneous injuries from contaminated sharps. OSHA published these revisions January 18, 2001, with an effective date of April 18, 2001. Sample engineering control evaluation forms for evaluating safer engineering controls (i.e., sharps disposal container performance, needlestick prevention devices, safety syringes, intravenous access devices) are included in Appendix B of *Enforcement Procedures for the Occupational Exposure to Bloodborne Pathogens*published by OSHA on November 27, 2001.[68] The CDC, OSHA, and NIOSH have published a joint document, which is not regulatory, to assist with decreasing needlesticks in the operating room through the use of blunt suture needles.

Airborne Precautions, Resistant Organisms, and Transmissible Spongiform Encephalopathy Patients in the Operating Room

Communication and screening systems should be in place so that operating room personnel are aware of or informed about *before surgery*any infectious diseases carried by the surgical patient (i.e., airborne organisms, TSEs, drug-resistant bacteria).

The following precautions are taken:

1. Only emergency or medically necessary surgery is performed on a patient with suspected/proven tubercular disease because operating rooms are positive-pressure environments. Patients with suspected or proven tuberculosis (TB) are isolated in negative-pressure rooms. This holds true for patients with varicella infection as well.
2. Such a procedure should be performed at a time when minimal numbers of other surgeries are occurring and with a minimal number of personnel. The use of portable HEPA filters should be considered for increased protection of healthcare personnel. The rebalancing of air pressure within operating suites to accommodate a surgical TB or varicella patient is not recommended by the AIA.
3. A bacterial filter is placed on the patient's anesthesia breathing circuit at the endotracheal tube or expiratory side of the circuit. The entire circuit should be changed after the surgery is completed.
4. NIOSH-certified personal respirator masks are appropriate for respiratory protection of personnel in the operating room with a patient with respiratory TB or where irrigation of an abscess or organ infected with *Mycobacterium tuberculosis*takes place.
5. During postoperative recovery, the patient is monitored in a private room with a negative pressure pattern (if available, or, alternately, in a private room with a portable HEPA unit), as required for TB isolation rooms.

LATEX ALLERGIES IN STAFF AND PATIENTS

To reduce exposure to latex and prevent latex allergy, nonlatex gloves are available for barrier protection. However, careful consideration should be given to the barrier protection effectiveness of gloves made from different materials, especially when there is a potential exposure to bloodborne pathogens or biohazard risks.

Although gloves manufactured from different materials may have comparable barrier properties when directly removed from the box and tested, actual on-the-job barrier performance may be quite different. Rego and Roley[69]compared the barrier integrity of gloves made of natural rubber latex, polyvinyl chloride (vinyl, a synthetic copolymer), and nitrile (acrylonitrile butadiene) under controlled conditions that simulated clinical use and were specifically designed to mimic patient care activities. A total of 2,000 gloves were evaluated. They found higher in-use leakage rates associated with all vinyl gloves, indicating decreased durability and potentially compromised barrier protection. Stretch vinyl exhibited lower failure rates than standard vinyl. The nitrile and latex gloves evaluated were comparable in terms of barrier performance characteristics.

An earlier investigation implicated one particular brand of vinyl examination glove with an increased number of cases of herpetic whitlow in medical intensive care unit nurses who routinely gloved for secretion contact.[70]In a 300-mL water-tightness test, seven brands of vinyl gloves failed at rates of 4 to 28 percent (average of 11.1 percent, or 132 of 1,200), and seven brands of latex gloves failed at rates between 0 and 2.6 percent (average of 1.4 percent, or 24 of 1,750). The brand of vinyl glove that had been in use in the medical intensive care unit had a 28 percent failure rate. The quality of gloves varied greatly. Nitrile gloves were not evaluated in this study.

Preoperative assessment for surgical patients should include screening for latex allergy.

Further research and development on latex led to knowledge about latex allergies. The term latex refers to natural rubber latex, the product manufactured from a milky fluid derived from the rubber tree, *Hevea brasiliensis*. Latex allergy is a reaction to certain proteins in latex rubber. Latex proteins become

fastened to the lubricant powder used in some gloves. When workers change gloves, the protein/powder particles become airborne and can be inhaled. Although the specific amount of latex exposure triggering sensitization or an allergic reaction is unknown, repeated exposure to latex proteins increases the risk for developing allergic symptoms.

Symptoms of latex allergy involve skin redness, rash, hives, itching, respiratory symptoms (i.e., runny nose, sneezing, itchy eyes, scratchy throat), asthma (i.e., difficulty breathing, coughing spells, and wheezing), and shock. The most common reaction to latex products is **irritant contact dermatitis**; developing dry, itchy, irritated areas on the skin, usually the hands, and caused by irritation from wearing gloves and by exposure to the powders added to them. Irritant contact dermatitis is not a true allergy. **Allergic contact dermatitis**results from the chemicals added to latex during harvesting, processing, or manufacturing that cause a skin rash similar to that of poison ivy and is not a true allergy.[71]

CONTROLS USED TO REDUCE THE RISK FOR SURGICAL SITE INFECTIONS

Prophylactic Antibiotics

Appropriate administration of prophylactic antibiotics can help to prevent SSIs. The CDC and the American Society for Health System Pharmacists synthesized the literature to produce comprehensive guidelines concerning administration of prophylactic antibiotics across a wide range of procedures.[15,72]

Prophylactic antibiotic agents should prevent SSI, prevent SSI-related morbidity and mortality, reduce length of stay and costs, create no adverse events, and have no impact on the patients, flora or the hospital.[72]Prophylactic antibiotic administration refers to a brief course of antibiotic administered just before the beginning of surgery to reduce intraoperative antimicrobial contamination to a level that will not overwhelm host defenses and lead to infection.[73]

To maximize the benefits of prophylaxis, the antimicrobial agent used should be safe, inexpensive, and bactericidal, with an in vitro spectrum that covers the most probable contaminants for the operation.[72]

Timing the administration of antimicrobial prophylaxis so that the concentration present in serum and tissues is at a bactericidal level when the skin is incised is now the gold standard of care.

Intraoperative redosing of prophylactic antibiotics is recommended for long procedures.[72]Dosing of prophylactic antibiotic administration should be weight-based. Obese patients require a higher dose of antibiotics than other patients to obtain adequate serum and tissue concentration. Recommendations for redosing depend on if the duration of the procedure exceeds two half-lives of the agent or if there is excessive blood loss.

Perioperative Normothermia

A report for the U.S. Department of Health and Human Services, Agency for Healthcare Research and Quality, published in 2001, suggests that perioperative normothermia may reduce the incidence of SSIs in certain types of surgical procedures.[74]It describes the increased risk for SSIs in intraoperative hypothermic patients resulting from lowered tissue oxygen tension caused by dermal vasoconstriction, reduced blood flow to surgical sites, and impaired immune function—especially oxidative killing by neutrophils. Studies of patients undergoing elective colectomy were reviewed and indicated clear benefits to maintaining perioperative normothermia.[75]It is important to note that hypothermia may be

employed in some procedures to protect the myocardium and central nervous system during certain cardiac and neurological surgeries.[76]

The induction of anesthesia results in the redistribution of body heat, affecting every surgical patient under anesthesia. Normothermia is being viewed as a necessity and a monitoring quality indicator for surgical patients. Active measures used to maintain normal core temperatures (normothermia) during surgery include warmed inspired gases, warmed intravenous fluids, and forced air warming. Forced air warming is performed by placing an air blanket that circulates air warmed to 40°C over the surgical patient. Advanced warming devices provide warmth, unrestricted patient access, full patient visualization, and heat via pads, blankets, blowers, tubes, etc and so forth.[77]

Preoperative warming is gaining acceptance in practice. Prewarming or applying heat to the body before surgery works by adding heat to the periphery (i.e., arms, legs, etc.), which is typically 2 to 4 degrees cooler than the body's core. When a prewarmed patient goes under anesthesia, blood from the periphery flows into the core, but the temperature remains relatively constant. For an unwarmed patient, this same redistribution affect could cause a significant temperature drop and potentially contribute to the occurrence of SSI.[77]

Glucose Control

Perioperative medical complications are more common in patients with diabetes. Poor glucose control is an independent risk factor for SSIs in a variety of surgical procedures.[72,73,74,75,76,77,78,79,80,81,82,83,84,85]

The American College of Cardiology/American Heart Association guidelines for coronary artery bypass graft surgery also recommend continuous insulin infusion (CII) for diabetic patients.[86]Close attention to serum glucose levels is warranted throughout the entire perioperative period due to risk of hypoglycemia.[87]More studies concerning CII and outcomes of surgical patients are needed.

Indicator Reporting

In the era of mega monitoring with a multitude of indicators, the WHO presents a Safety Checklist for Surgical Teams. Its three-part segment focuses simply on sign-in, time-out, and sign-out phases of a surgical procedure for the surgical team to complete. The purpose is reduction of SSIs while saving patient lives.[88,89]

Institute for Healthcare Improvement (IHI)'s 5 Million Lives Campaign began in December 2006 as a means to prevent 5 million incidents of medical harm over a 2-year period. This prevention effort consisted of 12 interventions, of which SSIs were number 10. Volunteer enrollment offered choice of indicators to implement, tools for data measurement and submission, and monitoring of inpatient mortality rates.[90]When the campaign ended in 2008, there were over 4,000 hospitals enrolled with more than 2,000 hospitals pursuing each of the 12 interventions. The campaign's results showed improvement in patients' outcomes.[91]

Annually, The Joint Commission publishes its National Patient Safety Goals (NPSGs) as a means to promote specific improvements in patient safety, particularly in problematic areas. These NPSGs are evolving, increasing indicators that The Joint Commission evaluates for compliance in healthcare organizations. Timely, continual review of the entire list is essential for inclusion in the overall facility infection prevention agenda.[90]

Initiated in 2003 as a national partnership of 10 federal agencies and professional organizations, the SCIP strives to improve patient safety by reducing postoperative complications. As would be expected, SSIs are number one, with emphasis on prophylactic antibiotic administration, glucose control, hair removal, and normothermia process measures. Participating hospitals report their data collection and outcome measures to SCIP, who aggregates the data. SCIP hopes to prevent 13,000 perioperative deaths and 300,000 surgical complications annually through enhanced facility performance in the specified targeted indicators.[90]

Additionally, the CMS has initiated a scope-of-work (SoW) approach tied to the reimbursement arm for healthcare facilities. CMS' healthcare quality improvement initiatives for Medicare providers focuses on refining care delivery systems to make sure patients receive the right care at the right time, particularly patients from underserved populations. Its ninth SoW began on August 1, 2008, and lasted for 3 years under the Patient Safety theme—improved inpatient surgical safety and heart failure rates are the first measures.[90,92]The tenth SoW began in 2011 and will be in place until July 2014, focusing on a 40 percent decrease of HAIs, which includes SSIs.[93]

The Society for Healthcare Epidemiology of America (SHEA) and Infectious Diseases Society of America (IDSA) crafted a supplement entitled *A Compendium of Strategies to Prevent Healthcare-Associated Infections in Acute Care Hospitals*. The reporting requirements are cited in the individual sections on practice recommendations, which include SSIs.[94]

INTERDISCIPLINARY COLLABORATION

Collaboration among infection prevention, environmental services, pharmacy, purchasing, and perioperative personnel is essential for prevention, control, and reduction of SSIs. Of special note is the vital role of environmental services personnel as the frontline in preventing infection. Not only do environmental services personnel lead the battle against challenging microbes contaminating healthcare environments, but also truly believe they are the infection prevention eyes and ears in the trenches to observe infection prevention infractions. This environmental services role is being recognized for its value to overall prevention efforts for safer patient care. Dr. Philip Carling reported the results of monitoring cleaning in the operating rooms. The study, using a black light and marker solution, allowed environmental service staff to be educated regarding where cleaning was not being performed on high-touch surfaces.[95]

Infection prevention is an interdisciplinary pursuit that involves open communication and outcome resolution in the following areas.

1. Surveying and reporting of SSIs (see other chapters in this text for relevant information): This should include (a) establishment of uniform criteria/definitions for SSIs; (b) stratification of rates by department, service, surgeon, time, procedure, classification, and so on; (c) reporting of results of surveillance activities to the surgical team planning strategies for reducing SSI rates; (d) reporting of SSI rates by surgeon in a confidential manner on a routine basis; and (e) ongoing quality improvement activities in the operating room. Local and state regulatory agencies should be checked for the most up-to-date reporting requirements.
2. Surveillance and outbreak investigation (see **12. Outbreak Investigations**): It is important to conduct a formal epidemiological investigation when a cluster of infections involves an unusual organism.

3. Product evaluation (see **7. Product Evaluation**): Essential in all product and equipment purchases that directly or indirectly affect the patient, the perioperative personnel and surgical outcomes require rigid scientific research study to validate their beneficial addition to the armamentarium of infection prevention for SSI. Constructive interdisciplinary facility committees should include perioperative members, central service personnel, materials management, and infection preventionists, at a minimum. These committees should use an objective written process to guide their product analyses before purchase.
4. Processing procedures (see **106. Sterile Processing**): Implementation of standards with the new technologies is vital to successful preparation for the particular operation. Continual competency verification is important to maintain consistency and accuracy in fomite preparations for safe patient outcome.
5. Written policies and procedures, including dress code, isolation, employee protection, environmental parameters, and regulatory requirements.
6. Mutual collaboration for new construction or extensive remodeling (see) from the design phase to completion, with respect to architectural construction codes, infection prevention requirements, environmental cleanliness, surgical technology, and safety measures.
7. Mutual assessment of new technologies related to infection prevention standards (e.g., intricate surgical techniques, complex equipment, specialized processing procedures, supply technology materials, microfiber, etc.).
8. Operating room waste management in concert with the institutional waste management program (see **113. Waste Management**).
9. Ambulatory surgery center practice guidelines.
10. Environmental cleanliness and disinfection procedures (see **107. Environmental Services**), as well as laundering and linen processes (see **111. Healthcare Textile Services**), are frequently responsibilities of environmental services.

Conclusions

The costs of SSIs are realized through increased lengths of hospital stay, ambulatory nursing visits for wound care, pharmacy costs for antibiotics, increased outpatient and emergency room visits, diagnostic laboratory studies, reoperation rate, and physician expenses.[96] Approximately 27 million surgical procedures are performed each year.[2] Prevention measures to decrease SSIs has become a global focus. The SHEA/IDSA *Compendium of Strategies to Prevent Surgical Site Infections in Acute Care Hospitals* is a concise compilation of practical recommendations to implement and prioritize SSI efforts.[97]

Future Trends

Interdisciplinary collaboration on research and future trends should include examination of the following: (1) rituals and sacred cows; (2) sterile versus clean practices; and (3) new technologies such as impregnated sutures and catheters, implanted devices and materials, wound closure, minimally invasive and imaging procedures, blood product alternatives, nanotechnology, and many more. Two recent studies indicate for both cardiac surgery and neurosurgery that use of antimicrobial suture may reduce surgical infections.[98,99]

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1400 Crystal Drive, Suite 900
Arlington, VA 22202

202-789-1890 / info@apic.org